RE-DEFINING THE CONCEPTS OF WASTE AND WASTE MANAGEMENT

Evolving the Theory of Waste Management

EVA PONGRÁCZ

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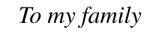
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Abstract

In an attempt to construct a new agenda for waste management, this thesis explores the importance of the definition of waste and its impact on waste management, and the role of ownership in waste management. It is recognised that present legal waste definitions are ambiguous and do not really give an insight into the concept of waste. Moreover, despite its explicit wish of waste prevention, when according to present legislation a thing is assigned the label of a waste, it is going to be treated like waste, implicitly legislation thus amasses waste. The philosophical ramifications inherent in such definitions mean that they are not capable of constructing a system that, by its very nature, results in a sustainable waste management system. It is also a fact that, while there are numerous practices as to how to deal with a particular type of waste, there is no theory of waste management. In this thesis, waste as a concept is analysed from the point of view of why and when waste is created. Using the PSSP language, waste is classified based on the Purpose and Performance attributes. New, dynamic definitions for waste and waste management are offered, which explain why waste is created and intrinsically offer a solution to how the problem could be solved. Additional waste-related concepts are introduced, which are thought to have great potential for improvement on waste regulation. The concept of ownership is explained as rights and responsibilities of waste creators/owners: it is thus crucial to raising awareness about waste. Ownership in itself often dictates which waste management options are preferentially adopted by a given community. The role of legislation in producing monitoring systems for the transfer of ownership as well as abandonment of ownership is analysed. To avoid obstacles to resource conservation due to materials being considered waste, a definition for non-waste is introduced. The new agenda for waste management thus focuses upon the development of more appropriate, sustainable definitions so that what is now commonly perceived as being waste will in fact be increasingly seen as resource-rich, 'non-waste'. The role of waste management is explained as control of all waste-related activities, with the aim of preventing, minimising or utilising waste. The need for a theory of waste management is explained, and the first building blocks of the theory are proposed. This thesis is offered as the first step toward scientification of waste management.

Keywords: definitions, non-waste, ownership, PSSP language, theory, waste, waste management



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One day in 1996, I walked into the office of Professor Veikko Pohjola, head of the Chemical Process Engineering Laboratory. I asked him straight out if he was interested in being my supervisor for research into a doctoral dissertation. We had never met before. To this day, I admire Professor Pohjola's courage to say yes to a stranger and put his trust in me. My utmost gratitude is expressed for his scientific guidance, for our fruitful discussions, and for his being so demanding all the time, because it challenged me and pushed me onward.

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When I came to Oulu in September 1993, for three months, neither my parents and sisters, nor I actually, ever thought that it would turn out to be a nine-year stay in Finland. When I left home, my nieces and nephews were children and teenagers, and now they are adults, all of them! I could never describe how much I missed the nest-warmth of my family during these years, and how much their love and unconditional support meant to me. What kept me going during these years were the provisions I brought from home: the

sense, vigour and integrity of my father, Dénes Pongrácz, and the persistence and stubborn willpower of my mother, Katalin Pongrácz. I also thank my wonderful sisters, Aurélia Pongrácz and Viola Olgyai, that despite the distance between us, we remained close at heart and soul. Warm thoughts also for my nieces: Andrea, Kristína and Eva; and nephews László, Tamás and Mátyás.

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Oulu, September 2, 2002

Eva Pongrácz

Preface

At my 15-year high school reunion, where everyone was 'established' and had decent jobs, I had to go there and say that I was still in 'school,' and that I was dealing with waste management. To some, waste management conjures up images of big vats of goo, with skimmers going over the surface. Doesn't really sound like something one should be proud of... Nevertheless, I considered it my duty to educate folks, raise their consciousness about waste, giving some guidelines about waste prevention, and waste handling. After all, picture it, this lovely blue, hospitable planet of ours is covered with waste. Litter is scattered throughout every latitude and altitude, from the hottest tropics to the coldest arctic, from the depths of the world's oceans, to the height of the tallest mountains. Interesting conclusions can be drawn about the water flow in the North Atlantic basin by following the route of floating debris on the ocean. You can find colourful plastic bottles on the pristine, untouched ice of the Arctic – sounds like blasphemy. Mount Everest is so heavily littered with trash that they had to organise a clean-up. That majestic mountain is decorated with tonnes of waste that the conqueror left there: bottles, canisters, batteries, mountaineering equipment, packaging waste, etc.

During the whole reunion, the theme of most of the discussions I had with old chums revolved around waste. I just wanted to make sure, please, if you ever see a separate waste container, do use it, and for heavens' sake, never put any other type of glass but bottle and jars in the bottle bank. At one point, Tibi, a jovial fellow, cried out: "Gee, mention any subject to Eva and she'll immediately associate it with waste. Were you to mention Space to her, she will still think of waste." Well, what do you know? Was he right! Space, the final frontier... Tonnes of debris orbits Earth: dead spacecrafts, discarded rocket bodies, cast-offs, remnants of satellite break-ups. Since 1961, more than 150 satellites have blown up or fallen apart, either accidentally or deliberately. And most of it is still up there; a cloud of lethal debris. Remember any science fiction movie, where the spacecraft had to navigate through a meteor belt? And you thought you had to watch for the big ones. At a speed of near to 15 km/s, collision with a one-centimetre pebble can destroy a spacecraft. Even a tiny grain of paint could wreck a mission: there are an estimated 300,000 pieces of debris greater than four millimetres, large enough to damage most spacecraft out there. I guess Tibi was right, I can think of waste in relation with anything, simple because it is everywhere!

Abbreviations

ALS Aerobic Landfill System

APME Association of Plastic Manufacturers in Europe CEFIC European Chemical Industry Council (in English)

DFE Design for the Environment DSD Duales System Deutschland European Court of Justice **ECJ**

European Environmental Agency **EEA European Economy Community EEC** The European Topic Centre for Waste ETC/W

The European Topic Centre for Waste and Material Flows ETC/WMF

European Union EU

EWC

European Waste Catalogue International Council on Metals and the Environment **ICME**

ΙE Industrial Ecology

Integrated Emissions Inventory IEI

IPPC Integrated Pollution Prevention System Institute for Prospective Technology Studies **IPTS**

IWM Integrated Waste Management

LFG Landfill gas

MSW Municipal Solid Waste

MSWM Municipal Solid Waste Management

Organisation for Economic Co-operation and Development OECD

PE Polyethylene

PER

Polluting Emissions Register Purpose, Structure, State, and Performance PSSP

Association of Packaging Technology and Research (In English) PTR

Research and Development R&D

National Technology Agency of Finland (in English) TEKES

United Nations Environmental Programme UNEP

Technological Research Centre of Finland (in English) VTT Research project on the efficacy of waste policy instruments WAPO

WEEE Waste Electrical and Electric Equipment

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"Slowly the poison the whole blood streams fills.

It is not the effort nor the failure fires.

The waste remains, the waste remains and kills.

It is the poems you have lost, the ills

From missing dates, at which the heart expires.

Slowly the poison the whole blood stream fills.

The waste remains, the waste remains and kills."

William Empson

1 Introduction

During previous research on the environmental effects of packaging, the author became interested in municipal solid waste management, its intricacies, the vast range of influencing factors and the consequent multi-disciplinarity of the field. All thing considered, waste management involves engineering ingenuity, logistics, management in the true sense of the word, economic and legal factors, and environmental and social implications. What waste really *is*, and the different approaches to define waste were already intriguing to the author as waste packaging was being considered.

The implication that waste is something useless has been troubling. The author felt, and still feels, that it was unjust to treat an empty package as useless. Packaging is required to give protection to a product until it is entirely consumed. This means that most packages, especially the re-closable ones, such as plastic containers, glass jars, *etc.*, are still in perfect condition when empty. They can still have continued usage for the same purpose as designed: containment, protection and use of the product. Thus, discarded (waste) packages are not necessarily useless, they are just empty. It was also considered that there is a somewhat nonchalant attitude in the acceptance that there is waste and something has to be done about it. A proper and more specific definition ought to identify the particular reason for the waste arising, perhaps give a hint as to how to solve this problem, and, overall, view waste as being a problem. Waste was then described as "an unwanted, but not avoided output, whence its creation was not avoided either because it was not possible, or because one failed to avoid it" (Pongrácz 1998).

What is waste, or packaging waste in particular, had obvious implications for the author's research. It seemed impossible to compare or compute packaging waste data from different countries because one could not be sure that they meant the same thing. For example, it was puzzling whether a used, and now empty, returnable glass bottle is waste or not. If one does not return it, but throws it away with mixed waste, then it is certainly a waste. However, if it is returned and sent to be refilled, it is then not waste. Subsequently, what does it then mean when the data of total glass waste and the percentage of it being **re-used** is observed? If it is re-used, why is it counted as waste? Similarly, the author was unable to define durable packaging containers: if one uses the empty, sturdy plastic ice-cream box to freeze portions of left-over food in, is one now re-using packaging waste, or has it actually ever been waste? The box had a short-term

lifespan as a carrier of a perishable product, ice-cream, but the end-user might re-use it for years to come as a freezer box. Must it still be referred to as packaging waste?

Viewed from such a perspective, it is understandable that the author would choose a theoretical research into waste management as a theme for a doctoral dissertation. The actual research was begun in May 1997. The first aim was to arrive at a clearer definition of waste. The author collected, from various sources, descriptions of waste and categories of wastes and analysed them. The main interest was **why** and **when** is something called or perceived as waste. Looking at all the waste descriptions amassed, it was noted that they could be arranged into four distinct classes, which are not based on material characteristics, or source, but rather the reasons why they became waste. This new taxonomy was inspired by the PSSP language. This new taxonomy triggered the evolution of the waste definition and then the introduction of the ownership concept. From this, newer, progressive definitions and a conceptual analysis of waste management followed

This work is somewhat different from the accepted, mainstream understanding or practice of waste management. On a daily basis, ordinary citizens deal with garbage: discarded things in the household waste basket. Garbage and waste are not the same thing. Essentially, they are not different, ostensibly they are just not the same. Similarly, waste management is not only about garbage collection. There is a need to augment traditional waste management, not replace it. The fact that a Theory of Waste Management is needed does not negate the need to continue to do traditional waste management research. The purpose of this work is to complement the research traditionally conducted by waste management scientists. The author concedes that this work will not solve all the problems of waste management, not even all that are addressed and discussed; but waste management is an urgent problem for society and every contribution is important. There are no futile actions, every little step forward is to be appreciated. We are far from the stage when we can afford to neglect small contributions. This work is offered as an invitation to dialogue, to challenge, and to follow the author's perspective of viewing waste from a different standpoint.

As indicated in the subtitle of the thesis, it is, principally, a theoretical work. It could be considered that this title is perhaps provoking, but it is only meant to be thought-provoking. In common usage, theory is always contrasted with practice. In science they are not contrasts. Theory, in its origin, is the state of contemplation, as distinct from the state of action, said Campbell (1957). Theory thus explains what one could experience in reality. The premise put forward in this thesis is not (yet) a mature one but only a first step toward evolving the theory. The theory of waste management should be a coherent group of general propositions with their scheme of relations to explain the theoretical questions of the waste management domain.

Waste management is generally a practical discipline, searching out solutions to individual waste problems: reactionary solutions. Given that the everyday problems of waste management are so important to solve, it may even appear so that theorising, instead of acting, is a loss of time and/or effort. This study is offered as a step towards the scientification of waste management. It is expected that the insight that a comprehensive theory of waste management would give to the domain would greatly contribute to the achievement of the goals of waste management, which is to conserve resources and protect the environment and human health.

The thesis is based on the hypothesis that the way we describe the target prescribes action upon it. The inherent focal argument is that waste management is not only the art of how to treat waste. That is one part of it, a crucially important part, and the greatest respect is held by the author for those who are excelling in it. However, the way the author would like to see waste management develop is rather similar to the concept of Integrated Resources Management and Industrial Ecology. These fields encompass systems views and are holistic accounts of materials flows in society, rather than the last step of a material transformation line that starts from natural resource, and ends with everything, eventually, becoming waste and returned as such to Earth. This transforming of natural resources into waste will, in due course, be called a life-cycle, although it is more linear than cyclical.

For the purposes of writing this study, the author's perception of waste management is presented as it is being exercised, thought of, and described. Thus, Chapter 2 is a critical review of the state of the art, emphasising the problems to be solved. Chapter 3 is a review of waste-related legislation. Chapters 4 through 6 contain the principal arguments put forth in this thesis about waste, waste management and the proposed definitions. Chapter 7 contains proposals toward evolving the theory. The theses of this work are expressed in Sections 7.8 and 7.9. Lastly, Chapter 8 presents an analysis of packaging. Finally, Chapter 9 contains the conclusions of the work.

According to T.S. Kuhn, each science begins with chaos of isolated suggestions by solitary authors. May this be the beginning of the chaos.

2 The state of the art of waste management

"Those who give flight to ready and rapid practice before they have learned the theory resemble sailors who go to sea in a vessel without a rudder." - Leonardo da Vinci

To complement Leonardo's analogy, it is possible to associate faulty waste management practices with sitting in a leaking vessel and frantically bailing water, rather than locating the leak and plugging it up. The main objective of waste management seems to be to remove waste. At waste management conferences, one hears countless presentations on how to handle, transform, utilise, or contain waste in more and more ingenious ways. One may even accept that this is the way it should be. We just accept as fact that the waste is there, it comes from somewhere and always will, and waste management practitioners do their best to help do away with it, or at least put it out of sight. Waste management is, therefore, merely a reaction to waste. What about the man on the street? It is the duty of the housing facilities or municipalities to provide waste containers. The citizen dumps his waste there and it is no longer his problem. He may complain that the place looks messy, the containers are ugly and dirty and repugnant to the touch, and they stink. After a long weekend, when the containers overflow with plump plastic bags, and the wind is chasing pages of old newspapers, he can just blame the municipality or the Waste Collection Company, but never himself. After that crucial moment when he dropped his own plastic bag filled with trash into the container, a strange sort of amnesia sets in, and he forgets all about having anything to do with that obnoxious mass.

In the 1960s and 1970s, the sight of towering smokestacks was the sign of affluence, technical development and advancement. Over the past forty years, we have learned the detrimental effect air pollution had, and still has, on our health and the environment. Waste production today is associated with affluence and the level of consumerism. "We have met the enemy and he is us," Walt Kelly's famous cartoon character once said. This, however, should not mean that we could not maintain a high standard of living and comfort without ever being buried in growing hills of waste.

This chapter is mainly a description of the state of the art of waste management: the actual methods and attitudes on a local and global level.

2.1 Sources of waste

Waste represents an enormous loss of resources both in the form of materials and energy. Indeed, quantities of waste can be seen as an indicator of the material efficiency of society. Waste generation is increasing in the European Union (EU), and amounts to approximately 1 300 million tonnes a year (Munck-Kampmann 2001). Manufacturing, mining and quarrying remain the main sector contributors. Figure 1 illustrates the waste generation by sector in the EU.

In Finland, it is estimated that annual waste generation amounts to some 65-70 million tonnes. Waste statistics cover all waste materials starting with primary production, except logging residues left in the forest. Figure 2 illustrates waste generation for sector excluding agricultural waste. There are no comprehensive data for all waste types for one and the same year. This figure is based on information from different sources and refers to different years, and is, to some extent, based on statistical and calculated values, and they are not, as such, comparable with international levels. (Ministry of the Environment 1998.)

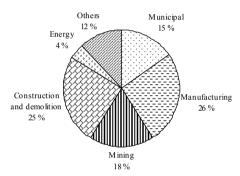


Fig. 1. Waste generation by sector in EU (OECD 1997).

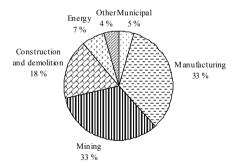


Fig. 2. Waste generation by sector in Finland (Ministry of the Environment 1998).

Solid waste is also increasingly produced as an attempt to solve other environmental problems such as water and air pollution. Some of these wastes give rise to new problems – examples include sewage sludge and residues from waste management facilities; for instance cleaning of flue gases from waste incineration.

While total waste quantities are a measure of resource loss, the environmental impact of waste cannot be analysed by looking at quantity alone. Dangerous substances in waste, even in small quantities, can have a very negative impact on the environment. The relative environmental impact of waste is related to both the quantity and the degree of hazard associated with it. There are, therefore, two aspects to waste generation: quantitative, *i.e.* how much is generated, and qualitative, *i.e.* the degree of hazard.

2.1.1 Municipal waste/household waste

The term 'municipal waste' is not unambiguous, and it has been confused with household waste. Until now, the two terms have been used in the following way (Fisher 2000):

- Municipal waste is first of all a management/collection concept. Municipal waste is waste collected by, or on behalf of the municipality. Municipal waste activities, especially in the commercial market, vary strongly across the EU. Moreover, during the 1990s, the private sector has, in several countries taken over the responsibility of certain waste streams that were previously collected by or on the behalf of the municipality. Data and information on municipal waste could therefore be expected to be incomparable by nature.
- Household waste is a concept linked to waste generation and includes all waste from a unique source: households. However, many wastes will be generated by different sources and also collected by the same truck. For example, traditional waste (bagged waste) or glass waste is produced both by households and other sources such as offices, trade, restaurants, etc.

The unreliability and incomparability of data is illustrated in Table 1 and Table 2. Table 1 compares data of household waste and municipal waste in 1996 for EEA (European Environmental Agency) Member States¹, excluding Liechtenstein. The source of data are surveys of the Organisation of Economic Co-operation and Development (OECD) and Eurostat. Denmark and The Netherlands are reported to have household waste generation figures of about 500 kg/capita/annum, which is twice that reported for Iceland and Finland, and 50% higher than that reported for Austria and Norway. Variations can also be found within one country over time.

Table 2 illustrates the growth in the amount of municipal waste in EEA Member States since 1975. Individual data may be unreliable due to differences of the countries' specification of municipal waste. While the growth in many countries is below 50%, in France and Italy it is over 100%, in Austria over 250%, and Finland reports a decline in the amount of municipal waste.

The EEA was initially established by the EU, thus all 15 EU states are members and, in addition, Iceland, Liechtenstein and Norway.

Table 1. Generation in kilo/capita of household and municipal waste in EEA member countries in 1996 or latest year available (Eurostat 1999).

Country	Household waste	Municipal waste
Austria	344	654
Belgium Brussels	366	655
Belgium Flanders	479	492
Belgium Walloon 1995	367	460
Denmark	496	540
Finland 1994	171	413
France 1995	435	597
Germany 1993	-	536
Greece	-	344
Iceland	242	558
Ireland	368	558
Italy	-	455
Luxembourg	-	461
Norway	293	536
Portugal 1995	-	353
Spain	-	390
Sweden 1994	-	364
The Netherlands	486	562
United Kingdom	442	476

Table 2. The amount of municipal waste in kilo/capita in EEA member countries (Eurostat 1995, Eurostat 1999).

Country	1975	1980	1985	1990	1996	Growth %
Austria	185	222	620	229	564	253.5
Belgium	296	313	343	-	492	67.2
Denmark	-	399	-	475	540	35.3
Finland	-	-	624	510	413 (1994)	-33.8
France	271	289	360	294	597	120.3
Germany	333	348	335	317	536 (1993)	61
Greece	-	259	296	304	344	32.8
Iceland	-	-	314	-	558	77.7
Ireland	175	186	-	312	368 [¤]	110.3
Italy	257	252	348	265	455	77
Luxembourg	330	351	445	357	461	39.7
Norway	424	416	472	474	536	26.4
Portugal	-	213	257	247	353	65.7
Spain	226	270	322	260	390	75.6
Sweden	293	302	374	317	364 (1994)	24.2
The Netherlands	-	498	497	43	562	12.9
United Kingdom	324	312	348	341	475	46.9

ⁿ No data available for municipal waste, data for household waste used instead

2.1.2 Waste Electrical and Electric Equipment

Waste Electrical and Electric Equipment (WEEE) is a complex mixture of materials and components. In combination with the constant development of new materials and chemicals having environmental effects, this leads to increasing problems at the waste stage. The WEEE waste stream differs from the municipal waste stream for a number of reasons (Commission of the European Communities 2000):

- The rapid growth of WEEE is of concern. In 1998, 6 million tonnes of WEEE were generated in the EU (4% of the municipal waste stream). The volume of WEEE is expected to increase by at least 3 to 5% per annum.
- Because of their hazardous content, electrical and electronic equipment cause major environmental problems during the waste management phase if not properly pre-treated. As more than 90% of WEEE is landfilled, incinerated or recovered without any pre-treatment, a large portion of various pollutants found in the municipal waste stream comes from WEEE.
- The environmental burden due to the production of electrical and electronic products exceeds by far the environmental burden due to the production of material constituting the other sub-streams of the municipal waste stream.

Due to these considerations, WEEE is one of the priority waste streams of the European Community. According to the study commissioned by the Electric and Electronic Industry Union of Finland, the amount of electric and electronic scrap in Finland in 1996 was approximately 94 000 tonnes, of which approximately half went to landfills (Uitto 1999).

2.1.3 Manufacturing waste

According to the OECD environmental data compendium (OECD 1997), 26% of the waste generation in the EU comes from manufacturing (see Fig. 1). Since data from most countries is incomplete, this data, however, shall be regarded as the best available approximation.

In general, the development in waste generation from manufacturing is increasing (see Table 3), only France and Germany have reported decreasing amounts of manufacturing waste. At the EU-level, no detailed information exists at the moment about waste generation related to different branches of manufacturing. For manufacturing waste, there are significant variations between Member States; in some countries (notably Germany and Denmark), the ratio of waste generation to manufacturing GDP is much lower than in others. This may be an indicator of the use of cleaner technology (including internal recycling) in production, but it can also be as a result of differences in industrial structure. As an example, much of the heavy industry in Western Europe has been closed in the last few decades due to competition from Eastern Europe and Asia. (European Topic Centre on Waste and Material Flows 2002a.)

Table 3. Waste	from manufacturing.	Stated by	country, ye	ear and	in tonnes	x 1000
(European Topi	c Centre on Waste and	Material Fl	ows 2002a).			

Country	1990	1992	1993	1994	1995	1996	1997
Austria					10 468	14 284	
Belgium				13 365			
Denmark				2 309	2 563	2 632	2 736
Finland		15 400					
France			105 000	101 000			
Germany	84 051		65 119				
Greece		512 ¹			2 905		
Iceland		8		8	9	9	9
Italy					$22\ 208^2$		
Norway	$2\ 000^3$				3 288 ⁴	2 875 ⁴	
Portugal				418^{6}			
Spain				13 800			
The Netherlands				19 200	19580	19 970	
United Kingdom	56 000 ⁷				$56\ 000^3$	$56\ 000^3$	

¹ partial total, ² may include some mining and quarry waste, ³ rough estimates based on experts' opinion, ⁴ based on an interview, ⁵ based on a sample survey, ⁶ only related to hazardous waste excluding extracting industry, includes 6 million tonnes from basic metal industries, the remaining 50 million tonnes is a broad estimate

2.1.4 Hazardous waste from manufacturing industries

All waste, hazardous or not, is subject to Directive 75/442/EEC on Waste. Hazardous waste is also subject to Directive 91/689/EEC. A list of the hazardous wastes covered by the Directive is to be drawn up on the basis of the categories, constituents and properties set out in the Annexes to the Directive. Member States should ensure that hazardous waste is recorded and identified; they should also ensure that different categories of hazardous waste are not mixed, and that hazardous waste is not mixed with non-hazardous waste, save where the necessary measures have been taken to safeguard human health and the environment (European Council 1991a).

The European Topic Centre for Waste and Material Flows (ETC/WMF) has reviewed data on hazardous waste from different countries in order to make a comparison. Data was found to be scarce and difficult to compare in order to make a valid comparison. As stated, it was important that the reported data were based on the same definitions. The total quantity of hazardous waste of EEA countries – not including Iceland, Brussels and Wallonia that could not provide information – according to economic activity (NACE codes) can be estimated at 23.5 million tonnes. (Brodersen *et al.* 2002b.)

2.1.5 Construction and demolition waste

Construction and demolition waste are other priority waste streams of the EU. They account for approximately 25% of the total waste generation in the EU (see Fig. 1). The main environmental concerns associated with construction and demolition waste is the presence of hazardous substances in the waste. Asbestos, for example, which in itself is hazardous; and PVC, which in some treatment techniques causes emissions of toxic gases (dioxins). (European Topic Centre on Waste and Material Flows 2002b.) In addition, the use of raw materials from gravel and sandpits (replacing recycling of construction and demolition waste) causes destruction of the landscape and may cause problems for the level and quality of groundwater. (Symonds 1999.)

Data on construction and demolition is scarce, only a few member countries have time series available and details are limited. The amounts of this waste are difficult to compare within the EU due to different definitions used. The percentage of recycling is 80% in Denmark, Germany and The Netherlands, and 30-50% in Finland, Ireland, and Italy. Recycling includes crushing of bricks and concrete for use as filling in new building material, or filling under construction to replace gravel. (Brodersen *et al.* 2002a.)

Due to construction being an indicator of growth and prosperity in Western societies, the overall political target, to prevent waste generation from increase, has only few chances for success but, on the other hand, the aim of improving the recycling activities is certainly achievable! A study in Sweden concluded that recycling building waste makes possible considerable savings of energy and scarce, or non-renewable resources. The potential to increase energy savings is about 20-40%. (Thormark 2001.)

2.1.6 Wastewater treatment plants

To protect the water in rivers, lakes and coastal areas, wastewater treatment plants have been, and will continue to be, expanded in numbers and in terms of more advanced treatment methods. This is a positive development for the environment. However, a side effect of this positive development is an increase in the amounts of sewage sludge. This is a challenge for the waste management practice and policy. (Brodersen *et al.* 2002a.)

Sludge can be a valuable fertiliser in agriculture. It provides a good source of phosphorus and it also contains nitrogen, which can be valuable, especially for crops with a long growing season (ISWA 1998). The organic content of the sludge can help improve the soil structure and, in general, sludge stimulates beneficial biological activity in the soil (DEPA 1997). The content of nutrients in sludge will increase with a more effective cleaning of wastewater. Phosphorus, being a limited resource, makes use of sludge for agricultural purposes an appealing solution for sustainable waste management. However, sludge is also contaminated with heavy metals, bacteria and viruses and a number of organic substances, and both EU and national regulations set limits for contaminant concentrations in order to protect the soil and humans from pollution (European Council 1986). Landfilling of sludge has hitherto been an inexpensive means of disposal, but both national restrictions and the Landfill Directive will make landfilling more expensive

(Christiansen 1999). Within the EU, the Landfill Directive provides restrictions on the landfilling of organic waste (European Council 1999).

However, incineration reduces the sludge to ash, which can then be landfilled. In most cases, supplementary fuel is needed in order to burn the sludge and there is usually no net gain of energy. (Johnke 1998.) One positive sign is the possible fall in content of heavy metals, combined with a higher content of nitrogen and phosphorus due to more efficient wastewater cleaning, which is at least realised in Finland, Denmark, Germany, and France (Report from the Commission 1999).

The European Commission expects the amount of sludge used for agriculture and soil conditioning to have increased significantly, by 73% by 2005, being 53% of the total output. The proportion of sludge incinerated is predicted to increase up to 25% of total, and the amount sent to landfill to decrease by 33% from 1992 to 2005. Due to more stringent demands for water treatment in the Council Directive concerning Urban Wastewater Treatment (European Council 1991b), many new treatment plants are due for completion by 2005. Consequently, the amount of sewage sludge will have been expected to increase by 50%: from 6.6 million tonnes of dry matter in 1992 to at least 9.4 million tonnes by 2005 (Report from the Commission 1999).

2.2 Waste management hierarchy

The hierarchy of waste management principles has been set as: waste prevention; recovery; and safe disposal (European Council 1991a). However, in the following subsections, the author will discuss the waste hierarchy in its 'old-fashioned' order of waste minimisation, re-use, recycling, incineration and disposal (Kirkpatrick 1992).

2.2.1 Waste minimisation

At the top of the hierarchy stands waste minimisation as the most desirable option. After all, what has not been produced, does not have to be dealt with. At a workshop in Berlin organised by the OECD in 1996, a definition of waste minimisation was worked out. According to which it encompasses these three elements in the following order or priority (Riemer & Kristoffersen 1999):

- preventing and/or reducing the generation of waste at source;
- improving the quality of the waste generated, such as reducing the hazard; and
- encouraging re-use, recycling and recovery.

This definition overlaps with the objectives of the waste management plans (Fig. 3).

However, the definition illustrated in Fig. 3 is very broad. In order to avoid duplication, a more strict definition for waste minimisation was agreed upon at the task meeting of the then European Topic Centre on Waste (ETC/W) – presently called European Topic Centre on Waste and Material Flows (ETC/WMF) – of the European Environmental Agency in Stuttgart, September 7th, 1998 (Fig. 4).

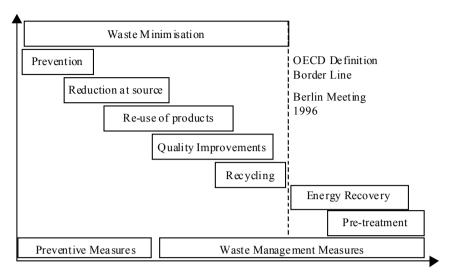


Fig. 3. OECD Definition on waste minimisation agreed at the Berlin Workshop (Riemer & Kristoffersen 1999).

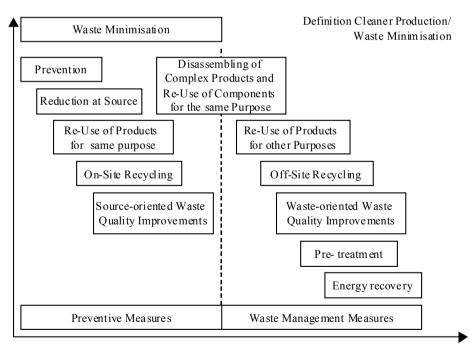


Fig. 4. ETC/W Definition of cleaner production/waste minimisation (Riemer & Kristoffersen 1999).

In the ETC/W definition, cleaner production/waste minimisation is only related to preventive measures. In detail, this means that waste minimisation includes (Riemer & Kristoffersen 1999):

- waste prevention i.e. reduction of waste by application of more efficient production technologies;
- internal recycling of production waste;
- source-oriented improvement of waste quality, e.g. substitution of hazardous substances;
- re-use of products or parts of products, for the same purpose.

According to the definition, waste minimisation does not include:

- external recycling;
- improvement of waste quality by sorting of waste;
- re-use of product or parts of products for any other purpose than the original;
- any kind of energy recovery.

The definition is closely related to the generating source only – on the one hand to the production process, and the other, to the end-of-life products.

What is actually waste prevention is not yet considered equally everywhere. For example, in a survey made by TEKES, the National Technology Agency of Finland, they report that "waste reduction research projects" are concentrating on issues such as home composting, reducing packaging waste, better waste separation and recycling of specific wastes (TEKES 2001). While home-composting could be argued to be 'on-site recycling,' none of the other listed options are waste prevention options. A more accurate expression would be recovery, or diversion of waste from landfill.

Furthermore, in an investigation requested by VTT, the Technological Research Centre of Finland, on technology development needs for waste management, none of the interviewed experts mentioned any direct waste prevention technology need. Rather, many thought that the most crucial development needed is in better waste separation and recycling technology (Granqvist & Kaila 1999). In reality, as the TEKES report also concluded, waste prevention starts at the design table: products have to be planned considering re-use, recycling, and refurbishment. Waste minimisation includes four rather different options.

The first possibility is **using less material to produce a product**, so that when it is thrown away, there is less waste created. This means that the function of the object has not changed, nor its fate. It is still assumed that the same object, be it a yoghurt cup, is still going to be thrown away. The fact that it is now of lighter weight should give us some sense of relief that now 'less' waste is discarded. Light-weighting of packaging, for instance, and the substitution of lighter materials for heavier ones, have long been parts of the competitive battle. Changes in lifestyle and technology have enabled fillers to offer larger packages that combine the commercial benefit of lower unit costs with the improved resource efficiency, resulting from a higher ratio of product-to-packaging material weight. The legislators recognising that this happens for commercial rather than environmental reasons have, for a long time, refused to give the packages and the packaged goods industry any political credit for it (Pongrácz 1998). It is questionable, however, whether light-weighting really leads to waste minimisation. Often, a reduced

strength, lighter, thinner package breaks more easily, thus leading to higher product wasting. As well, in the case of packaging, reducing the amount of primary packaging often leads to increased amounts of secondary and transport packages.

Secondly, **creating durable products**. Again, the function of the product is unchanging, neither is the assumption that the product, *e.g.* a battery, is going to be useless and thrown away after some time. Waste minimisation happens due to the fact that this 'new' battery lasts longer than its predecessors, thus even when the consumer continues using batteries with the same intensity, during the same period, a lesser number batteries will be thrown away.

The third facet of waste minimisation is in actuality **waste evasion**: the effort to avoid waste creation. There are two ways to waste evasion: one method is to change the production process, so that less production waste is created. The other is to try and utilise the created waste so it will no longer be waste. In the United Kingdom, where 90% of household and 73% of industrial waste is landfilled, waste minimisation is seen as the best way to reduce impact of waste on the environment, especially in the industrial and commercial sectors. Businesses are going to increasingly face the full cost implications of the waste they produce so as to encourage minimisation. Recent thinking has concentrated upon the synergy between industrial/commercial and domestic waste minimisation developments and new approaches are being considered to drive domestic programmes. (Phillips *et al.* 1999.)

The first industrial/commercial waste minimisation clubs were formed in the UK during the early 1990s. To date, there are about 150 such waste minimisation clubs (Clarkson *et al.* 2002). Although some have been unsuccessful, the majority have shown that waste minimisation clubs successfully tackle information and market failures, yielding financial benefits, improved environmental performance, and potentially improved competitiveness (Pratt & Phillips 1999). These clubs have demonstrated that significant reductions can be made in waste occurrences, especially solid and liquid wastes. The introduction of minimisation methodology has resulted in improved resource efficiency, especially for water, and as such provides a model that points the way to more sustainable waste management (Phillips *et al.* 1999a).

The 19 club members of the Northamptonshire Resource Efficiency Project reported £1.9 million total savings, and possible additional savings of £1.24 million, over the length of the project (Cheeseman & Phillips 2001). Examples of successful club projects (Phillips *et al.* 1998, Phillips, *et al.* 1999b, Adams *et al.* 1999, Pike & Phillips 1999 and Clarkson *et al.* 2002) illustrate that the impact of waste minimisation methodology can encourage a culture of waste reduction, not just within businesses, but in the community as a whole. Actual waste minimisation in industry has also been argued to be done merely for economic reasons (TEKES 2001). It is understandable that money-saving is the chief motivation for industries to engage in waste minimisation programmes. However, it does not diminish the environmental credit of waste minimisation.

Lastly, substitution, in that **using less harmful substances** is also considered as waste minimisation. In this case, effort is made that an expected hazardous waste flow is replaced with a less dangerous one. Take the example of halogenated solvent wastes: halogenated solvents are used for surface treatment, dry cleaning, chemical extraction, solvents for rubber and plastics processing, *etc*. They are regarded as hazardous, as they accumulate in fatty tissue, causing partial decomposition, and will degrease skin, and

cause eye irritation. They are carcinogenic, and some solvent vapours affect the ozone layer. (Euroenviron 1993.) Pressure is on reducing solvent production, which is the actual waste minimisation effort. However, given the hazardous nature of this substance, minimisation only is not enough. The main goal is substitution with the current usage of halogen-free degreasing solvents, and the development of inorganic degreasers. In this case, we can still expect solvent waste, but it will be less dangerous. The best option yet is complete avoidance of solvent wastes. In Finland, a company by the name of Environics has avoided the use of solvents for dry coating by applying heat treatment to composites, and by applying electron beams to give strength to plastic sheets.

The importance of waste minimisation cannot be over-stressed. Robert Ayres, he who coined the term "industrial metabolism," has concluded that 94% of the materials extracted for use in manufacturing become waste before the product is even made, 80% of products are discarded after a single use (Ayres & Ayres 1996). Hawken (1994) estimated that 99% of the original materials used in the production of, or contained within, the goods made in the U.S.A. become waste within six weeks of sale. Clearly, people have a lot to learn about reducing waste, and "efficiency is the cure for the wasting disease" (von Weizsäcker *et al.* 1997). Researchers of the Wuppertal Institute estimate that 10% of the Earth's population currently consumes 50% of its resources (Schmidt-Bleek 2000). The U.S.A., alone, uses a third of world materials today (Gardner & Sampat 1998). The Wuppertal Institute proposed the *Factor 10* idea which implies a 90% decrease in materials use by industrial nations over the next half century (Schmidt-Bleek 2000).

While it is true that the principle of waste prevention is universally accepted, the practice has lagged far behind. Salmenperä (2000) pointed out that, for long, no waste policy control mechanism was used to guide waste avoidance. Institutes on the European, governmental, or local authority level increasingly realise the importance of achieving the full potential of waste minimisation.

The OECD concluded that, even when conventional environmental and waste policy approaches have succeeded in attaining their own specific objectives, they have not been sufficient toward overall waste reduction. OECD-wide recycling has been increasing, but without waste prevention efforts, a near doubling of municipal waste within the OECD area is expected within the next 20 years. The first-ever OECD workshop devoted specifically to waste prevention was held in 1999; and a Reference Manual on strategic waste prevention was published to assist governments with actions that support increased resource efficiency and sustainable development. (OECD 2000.)

The Finnish Environment Institute is involved in a project called 'Waste prevention advisory campaign for small- and medium-sized enterprises.' In the project, different methods of advising and informing enterprises are tested. The results of the project are expected to create efficient means to carry out waste prevention counselling. The main target is to increase awareness and information of waste issues and to help reduce the amount of waste generated. The target is achieved by production of information and education material by organising extensive education and by building networks between waste management authorities, private enterprises, consultants and other actors in the field. (Salmenperä 2000.) An environmental guide to the machine and metal industry has already been published, providing advice in material and waste matters of enterprises (Forsell 2000).

Information and motivation play important roles in waste avoidance. Consumers, given eco-efficient choices, also play an important role in resources conservation. However, this requires not only education but also opportunities and incentives, which are infrequent. Tenants are generally not motivated to conserve electricity or water, neither are workers motivated to use public transportation. Environmentally superior products and services are not always available, and when they are, they are often more expensive, thus the inclination is to choose the environmentally inferior product. (Mela 2000.) These issues have to be addressed if society is to move toward sustainability.

As a positive initiative, let us look at the example of the Helsinki Metropolitan Area Council (YTV), which has also published a guide for waste minimisation for its general public (YTV 2002), and initiated a benchmarking project to help and motivate enterprises for waste minimisation. The benchmarking scheme is Internet-based, where enterprises can follow the amount of waste they create and compare it to data of other enterprises. Enterprises involved can use the 'Resource-saver' logo, and are also in competition, and rewarded if managing to significantly reduce the amount of waste they produce. (Huuhtanen 2000.)

2.2.2 Re-use

Many consider re-use as the second preferred option after waste minimisation. Re-use for the same purpose is included in the waste minimisation options, but re-use for another purpose is listed as "waste management option" (Fig. 4). However, re-use for another purpose is not included in recovery options (Table 4).

Table 4. Annex IIB of the Waste Directive: Operations which may lead to recovery (European Council 1991a).

R1	Solvent reclamation/regeneration.
R2	Recycling/reclamation of organic substances which are not used as solvents.
R3	Recycling/reclamation of metals and metal compounds.
R4	Recycling/reclamation of other inorganic materials.
R5	Regeneration of acids or bases.
R6	Recovery of components used for pollution abatement.
R7	Recovery of components from catalysts.
R8	Oil re-refining or other re-uses of oil.
R9	Use principally as a fuel or other means to generate energy.
R10	Spreading on land resulting in benefit to agriculture or ecological improvement, including composting and other biological transformation processes, except in the case of waste excluded under Article 2 (1) (b) (iii).
R11	Use of wastes obtained from any of the operations numbered R1 - R10.
R12	Exchange of wastes for submission to any of the operations numbered R1 - R11.
R13	Storage of materials intended for submission to any operation in this Annex, excluding temporary storage, pending collection, on the site where it is produced.

Apart from these, there is no other mention, or a generic definition, of re-use in the legislation. Re-use is only defined in specific cases:

1. In the Packaging Directive (European Council 1994):

"Re-use shall mean any operation by which packaging, which has been conceived and designed to accomplish within its life-cycle a minimum number of trips or rotations, is refilled or used for the same purpose for which it was conceived, with or without the support of auxiliary products present on the market enabling the packaging to be refilled: such re-used packaging will become packaging waste when no longer subject to re-use."

2. In the Directive concerning End-of-Life Vehicles (European Council 2000c):

"Re-use means any operation by which components of end-of life vehicles are used for the same purpose for which they were conceived."

Re-use thus appears to be understood as 'use for the same purpose.' To illustrate, the following definition was proposed to the European Commission, by a consortium (Lox 1994):

"Re-use is use, for the second or more time, of a product for the same purpose, under the same form and with the same properties of the material as the first use, the material having constantly remained under the same form between several uses."

The Council Decision on mineral oils (European Council 1999b) mentions a number of cases in which "waste oils which are re-used as fuel" as subject to exemptions, or reductions, in the excise duty charged on mineral oils. There is also a regulation about the "re-use of waste water to irrigate parks" in Madrid (Commission of the European Communities 1993). In none of these regulations is re-use specifically defined, but it appears to mean 're-use for different purpose from the original.' It is difficult to determine what should 're-use for another purpose' signify. Since there is no definition for it, one cannot ascertain if 're-using' waste oils as fuel is really re-use: it rather sounds like incineration. Furthermore, it can not be said that the waste water is re-used because it has not previously been used: it is a new product, an output from some industrial operation or households. It has *not previously* had a purpose. In fact, its *first* purpose will be use for irrigation; therefore, it is either the water re-used, *or* the waste water utilised.

The proposal then is that re-use for the same purpose and new purpose are to be defined separately, based on Lox's definition accordingly:

Re-use for the same purpose is use, for the second or other time, of an artefact for the same purpose, under the same form and with the same properties of the material as the first use, the material having constantly remained under the same form between several uses.

Re-use for another purpose is use of an artefact for a different purpose as the original one, under the same form and with the same properties of the material as at the first use, the material having constantly remained under the same form between several uses.

It is also proposed that 're-use for another purpose,' defined in this manner, be evaluated equally desirable as 're-use for the same purpose' and both considered waste prevention options.

2.2.3 Recycling

There is an ongoing debate of the value of recycling. The fact still is that, recycling, or material recovery in general, has a very high priority amongst recovery options. Reduction of waste through recycling has been promoted since the 1960s. Recycling is assumed to be more than just a response to the environmental crisis and has assumed a symbolic role in instigating a change to the nature of Western societies and the culture of consumerism. Many environmentalists assumed that there would be an inevitable shift from the 'throw-away' society to a post-industrial recycling society. The market-based view of recycling policy assumed that low levels of recycling can be attributed to different forms of 'market failure'. (Gandy 1994.) The Community strategy for waste management also considered that until scientific and technological progress is made and life-cycle analyses are further developed, re-use and material recovery should be considered preferable. Recycling was defined as (European Council 1994):

"Recycling shall mean the reprocessing in a production process of the waste materials for the original purpose, or for other purposes, including organic recycling but excluding energy recovery."

It is useful to distinguish three different forms of recycling: closed-loop recycling, open-loop recycling, and down-cycling, which can be defined as follows (Lox 1994):

"Closed-loop recycling is a recycling process in which a waste material is used for the same purpose as the original purpose or for another purpose requiring at least as severe properties as the previous application so that, after one or several uses, this material can be used back again for the original purpose."

"Open-loop recycling is a recycling process in which a waste material is used for another purpose than the original purpose and will never be used back again for the original purpose."

"Down-cycling is a recycling process in which a (fraction of a) material from a used product is used to make a product that does not require as severe properties as the previous one."

These definitions presuppose that we are dealing with a thing that has had some useful life and turned into waste. These definitions do not appear to cover by-products, given that they have not had a previous use. It thus seems that both re-use and recycling refer to things that have had a purpose and, for some reason, ceased to be used for that purpose. To avoid becoming waste, it is then either re-used or recycled.

However, what shall we call treatment options when the waste is a new, emerging product, an output from a process? It could be suggested to apply the expression **waste utilisation**, and be listed in recovery options as: assigning a purpose to a by-product that did not have a purpose.

Quinn (1997) rejects the view that some do not consider recycling as a pure form of pollution prevention, as it addresses the disposal of products rather than their generation. Self-confessedly, she has a broader concept of prevention, and includes recycling and reuse in the definition of pollution prevention. The ETC/W partly agrees with her, and partly not. As Fig. 4 illustrates, on-site recycling and re-use for the same purpose are

considered a waste prevention measure, while off-site recycling and re-use for different purpose are waste management measures.

2.2.4 Feedstock recycling

The expression 'feedstock recycling' is used for methods when the waste plastics energy content is used by other methods than simple combustion, also referred to as 'tertiary polymer recycling' (Horvat & Ng 1998). These processes are not recycling by the 'classical' understanding of the word. Since plastics are generally high calorific value products ranging approximately from 18 000 to 38 000 kcal/kg, utilisation for their energy alone or for related chemical production may be an alternative option (Bisio & Merrieam 1994). For example, one could then take the view that the crude oil content of the plastic is temporarily used by the plastic to serve as a package. After its function as a package has been served, the fossil energy is utilised. Feedstock recycling includes the proceeding methods.

Use in blast furnaces

The use of plastic waste in blast furnaces was first tested at the Stahlwerke steel works in Bremen, Germany. The plastic waste is used as a reducing agent to extract oxygen from the iron ore, substituting heavy oil currently used. (Myrttinen 1996.)

In Finland, according to a study on pyrolysis technology for waste plastics conducted at the Energy Centre of VTT, the blast furnace at Rautaruukki Raahe Steel Oyj consumes 250 000 t/a special heavy fuel oil for the production of reducing gas. Since the use of solid plastic waste involves significant additional investments, their interest is in using plastic oil obtained from the fluidized-bed pyrolysis process. As the plastic oil does not contain sulphur, its use involves process-technical advantages, as sulphur variations in fuel oil can be regulated with the aid of plastic oil. The plastic oil may also substitute for heavy fuel oil, either as such, or mixed with fuel oil, if the waste plastic does not contain chlorine. Plastic types produced from polyethylene and polypropylene were found to be the best suitable for the production of plastic oil. In Autumn 1999, blast furnace tests were carried out in Raahe Steel, and plastics were melted successfully in heavy fuel oil, without any additives. (Arpiainen *et al.* 1999.)

Thermolysis

Recently, much attention has been directed to thermolysis and hydrogenation as methods of producing fuel from polymer waste. It was found that synthetic diesel fuel produced from PE (polyethylene) has greatly enhanced properties compared to conventional diesel fuel. Thermolysis is performed at a temperature lower than 500 °C and in absence of oxygen. (Horvat & Ng 1999.)

Compared to incineration, thermolysis is considered as a viable alternative to treat MSW, especially in regions with a low population density. At the end of thermolysis, the waste will have lost approximately 60% of its weight. As opposed to incineration, thermolysis does not produce slag. There remains only a mixture of carbonaceous solid

fuel, metals, and minerals. (Braekman-Danheux *et al.* 1998.) The thermolysis process can be called thermolytic sorting, since it isolates the combustible organic compounds from the non-combustible ones (water, minerals, metals), and only the combustible ones are burned. Some differences between thermolysis and incineration are presented in Table 5.

Table 5. Thermolysis versus incineration.

	Thermolysis	Incineration
Principle	Physico-chemical transformation of organic matter into coal, hydro-carbons, gas and water.	Thermal destruction of material.
Operating conditions	Without oxygen, at temperature of about 500°C in an airtight enclosure.	At a temperature of 900-1 000°C, with oxygen-carrying air, in a static or rotating furnace.
Entering wastes limited	-	In humidity.
Energy recovery	Production of fuel (coal and hydrocarbons).	On-site continuous production either by electricity or heat-generated.
Gas processing	Supply and production of synthetic gas, emissions treatment, dry or semi-dry.	Requires processing equipment, either humid or semi-humid, to control emissions.
Dioxin emission	None.	Possible, treated by gas treatment.

Thermolysis has received great support in Belgium, where incineration is associated with dioxin emissions. According to de Broux (1997), a legally mandatory 1 500-page report initiated in Belgium indicates that "Municipal solid waste thermolysis is conceptually better than incineration"

Pyrolysis

Pyrolysis for the simultaneous generation of oils and gases can be convenient to obtain hydrocarbons and even recover crude petrochemicals, or to generate energy from waste plastics (Kiran *et al.* 2000). Pyrolysis involves heating of a feed in an inert atmosphere at a temperature ranging from 500 to 800°C, to produce three forms of energy: gas, liquid or charcoal. Pyrolysis is an extremely versatile process and the reaction products can be controlled by means of the type of process and the operating conditions. The main purpose is to convert biomass and waste into high energy condensable, so-called pyroligneous liquid, which is much easier to manage than bulky waste. Pyrolysis is an endothermic (heat-absorbing) reaction. While at higher temperatures the gas yield increases, char yield is maximised at low heating temperatures. (Aguado & Serrano 1999.)

Pyrolysis has been studied at VTT in Finland since 1986. The Energy Centre of VTT has conducted liquid bio-fuel (pyrolysis oil) research and development co-operation with Sweden, Canada, the U.S.A., Austria and The Netherlands since that time. Their core technologies analyses include fast pyrolysis liquid production for district heat production within a city, and production of slow-release fertilisers from fast pyrolysis liquids. (Solantausta *et al.* 2000.) At the Helsinki University of Technology, the two-stage processing of high-PVC solid waste with HCl recovery is thoroughly studied. The process involves pyrolysis of high-PVC solid waste in a fluidized bed at low temperature, which

gives a chlorine-free fuel for a fluidized-bed combustor (FBC) plus concentrated HCl. The process has thermal efficiency of approximately 36% depending on the pyrolysis temperature and the PVC content. Hydrochloride recovery can be above 90% at a pyrolysis temperature of 310°C. (Zevenhoven *et al.* 2002.)

Gasification

Gasification is, technically, a compromise between combustion and pyrolysis: it proceeds in reaction with air, oxygen or steam at temperatures in the range of 700 to 1 000°C. It can be considered to be a partial oxidation of carbonaceous material leading predominantly to a mixture of carbon monoxide and hydrogen (rather than carbon dioxide and water produced by direct combustion), known as 'synthesis gas' or 'syngas', due to its application in a variety of chemical syntheses. (Aguado & Serrano 1999.) These gases contain 'chemical energy' that can be 'tapped' as and when required.

The advantage of this technology, over straightforward combustion, is that the lower bed temperatures employed in the process give good chances that problematical elements such as potassium, sodium and chlorine can be retained in the ash (Barton and Ogilvie 1992). In Finland, gasification tests have been conducted at the Jalasjärvi gasification plant with waste preserved wood impregnated with toxic inorganic and/or organic chemicals (Vesterinen 1995). The VTT Energy Centre has also developed atmospheric pressure fluidized-bed gasification and gas cleaning, focusing on the development of the gasification process, as well as on the development of different gas cleaning concepts. One of the most essential applications has been gasification, and co-firing the gas in a large-scale PC (pulverized coal) boiler. Recently, this experience was applied to plastic-rich wastes. The aim was to develop gasification and gas-cleaning techniques for the use of plastic waste in energy production. (Nieminen 2001.)

Hydrogenation

Hydrogenation, usually in the presence of catalysts, is the final method of feedstock recycling considered. In the process, the polymers are cracked in a hydrogen atmosphere at a temperature in the area of 400°C and at a pressure of 300 bar. Compared to treatment in the absence of hydrogen, hydrogenation leads to the formation of highly saturated products, avoiding the presence of olefins in the liquid fractions, which favours their use as fuels. Moreover, hydrogen promotes the removal of hetero-atoms (Cl, N and S) that may be present in the polymeric wastes. (Aguado & Serrano 1999.) The end product is a synthetic crude oil, which can then be used as a raw material by the petrochemical industry. The hydrogenation method is used, for example, in the coal-oil plant in Bottrop, Germany (Myrttinen 1996). Hydrogenation suffers from several drawbacks, however, mainly the cost of hydrogen and the need to operate under high pressures.

2.2.5 Feedstock recycling versus mechanical recycling

A study by APME (Association of Plastics Manufacturers in Europe) assessed the environmental impacts of mechanical and feedstock recycling and energy recovery of

waste plastics. It was compared in terms of consumption of resources and environmental emission pollution potential.

With regard to the criteria "consumption of energetically exploitable resources" and "contribution to the greenhouse effect," these result in the following order of preference for feedstock recycling and energy recovery processes (APME 1995):

- use as feedstock in blast furnaces;
- thermolysis to petrochemical products;
- fluidized-bed combustion;
- hydrogenation, together with vacuum residue oils;
- incineration in domestic waste incinerators;
- fixed-bed gasification, together with lignite;
- gasification together with lignite in the fluidized-bed.

The first three processes reduce the contribution to the greenhouse effect in comparison to landfilling. All these processes reduce the eutrophication and acidification potential in comparison to landfill. The overall volume of waste produced was found least in the waste incineration. In summary, from an ecological point of view and on the basis of the comparative analysis of feedstock recycling and energy recovery, the following recovery processes are recommended (APME 1995):

- 1. Use as reducing agents in blast furnaces.
- 2. Thermolysis to petrochemical products.
- 3. Fluidized-bed combustion.

According to APME (1995) mechanical recycling processes have ecological advantages over feedstock and energy recovery processes, if 'virgin' plastic is substituted in a ratio of 1:1. With this prerequisite, mechanical recycling processes reduce the consumption of resources and emissions in comparison to feedstock recycling and energy recovery processes. However, because of the ageing of the material and presence of pollutants such as additives, colours and dirt, recycled post-consumer plastics can never completely replace virgin material. As a consequence of the restrictive technical limits, Plinke and Kaempf (1995) believe that physical recycling will not be the major route in plastics waste management and other routes must be applied. APME concurs, and asserts that if considerably less than 1 kg of 'virgin' plastic is substituted by 1 kg of waste plastic, mechanical recycling processes no longer have an advantage over feedstock recycling and energy recovery processes (APME 1995).

A more recent study by the Fraunhofer Institute in Freising, Germany, confirms that, when compared with feedstock recycling and energy recovery processes, mechanical recycling, in some instances, has the potential to achieve considerably greater environmental savings. If recycled plastics replace the use of 'virgin' plastics material, savings are realised. However, in other instances, if recycled plastics are used as concrete or wood substitutes, savings effects are, in general, considerably lower than in the case of feedstock recycling or energy recovery (Heyde & Kremer 1999). An inherent weakness in this report is that it addresses the plastics recycling situation up to the end of 1995, and does not cover options that are now available, such as PET recycling and further physical separation of mixed plastic waste (Hanisch 2000).

Another study quoted by Hanisch (2000), was conducted by the Ököinstitut in Darmstadt, Germany, and addresses whether environmental benefits from feedstock plastic recycling are worth the high collection and sorting costs. The results of the study indicate that feedstock recycling is environmentally beneficial compared to incineration, and costs of both options are converging (Dehoust *et al.* 1999). According to Dehoust in 1999, collection, sorting, preparation, and feedstock recycling of one metric tonne of mixed household plastic waste cost about DEM 2 100 (1 073 EUROS), whereas incineration costs DEM 1 080 (552 EUROS). However, the study calculates that in 2020, both costs will be in the area of 408 EUROS.

2.2.6 Incineration

Incineration has long been considered the second least-preferred waste management option after landfill. Now it is considered as one of the disposal options, as listed in Annex IIA (Table 6) of the European Community's Waste Directive.

Table 6. Annex IIA of the Waste Directive: Disposal Operations, (European Council 1991a).

D1	Tipping above or underground (e.g. landfill, etc.).
D2	Land treatment (e.g. biodegradation of liquid or sludge discards in soils, etc.).
D3	Deep injection (<i>e.g.</i> injection of pumpable discards into wells, salt domes or naturally occurring repositories, <i>etc.</i>).
D4	Surface impoundment (e.g. placement of liquid or sludge discards into pits, ponds or lagoons, etc.).
D5	Specially engineered landfill (<i>e.g.</i> placement into lined discrete cells, which are capped and isolated from one another and the environment, <i>etc.</i>).
D6	Release of solid waste into a water body except seas/oceans.
D7	Release into seas/oceans including seabed insertion.
D8	Biological treatment not specified elsewhere in this Annex which results in final compounds, which are disposed of by means of any of the operations in this Annex.
D9	Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds that are disposed of by means of any of the operations in this Annex (<i>e.g.</i> drying).
D10	Incineration on land.
D11	Incineration at sea.
D12	Permanent storage (e.g. emplacement of containers in a mine, etc.).
D13	Blending or mixture prior to submission to any of the operations in this Annex.
D14	Repackaging prior to submission to any of the operations in this Annex.
D15	Storage pending any of the operations in this Annex, excluding temporary storage, pending collection, on the site where it is produced.

The EU classifies incineration as "the main alternative disposal method to landfill," and explains its censure as follows (European Council 1997):

"Incineration produces toxins, and heavy metals. To prevent their release, expensive filters must be installed in incinerators. Used filters with highly concentrated contamination, together with the quarter of the waste's original weight, must still be landfilled."

Nevertheless, with the restriction on landfill imposed by the EC Landfill Directive, the construction of new incinerators can be expected, especially for countries with a high proportion of landfill disposal (Glinski & Rott 2000, Burnley 2001). The Community strategy for waste management notes and shares the concern of Member States at the large-scale movements within the Community of waste for incineration with or without energy recovery.

However, one would also invite the Commission to consider the scope for the amendment of Community legislation in relation to the incineration of waste with energy recovery in order to address this concern, and to present appropriate proposals.

In November 1999, the European Community adopted a common position to update the previous legislation on incineration of municipal waste (European Council 2000b). This tightens up emission standards for both new and existing installation and, most importantly, also applies to so-called co-incinerators, such as cement kilns and power plants. The reason is that some consider that incineration with energy recovery is a more profitable than a comprehensive recycling programme. Gandy (1994) thinks that the notion of an inevitable shift to a post-industrial 'recycling society' of the future represents a fundamental naïveté on the part of many environmentalists and policymakers over the underlying constraints – recycling infrastructure, secondary material market, degree of government control over the waste stream – on recycling in a capitalist economy.

The pro-incineration lobby have presented a range of instruments to illustrate the attractiveness of this option (Gandy 1994):

- No major alteration in the arrangements for waste collection is needed, and the management, construction and operation can be carried out in the private sector, thereby reducing the local and national tax burden;
- The volume of waste is reduced by 90%;
- Guaranteed market for the energy recovered;
- The income is expected to rise over time:
- Geographical concentration of waste in urban areas.

Petts (1994) listed the specific benefits of waste incineration as follows:

- 1. A reduction in the volume and weight of waste, especially of bulky solids with a high combustible content. Reduction achieved can be up to 90% of volume and 75% of weight of materials going to landfill.
- 2. Destruction of some wastes and detoxification of others to render them more suitable for final disposal, *e.g.* combustible carcinogens, pathologically contaminated materials, toxic organic compounds, or biologically active materials that could affect sewage treatment works.
- 3. Destruction of the organic component of biodegradable waste which when landfilled directly generates landfill gas (LFG).
- 4. The recovery of energy from organic waste with sufficient calorific value.
- 5. Replacement of fossil-fuel energy generation with consequent beneficial impacts in terms of the greenhouse effect.

It can also be added that incinerated ash can be utilised for production of asphalt and ceramic. Such production tests have been made in Japan to great success. In Japan, 75% of the annual 50 million tonnes of Municipal Solid Waste (MSW) is incinerated,

producing approximately 6 million tonnes of residue which is then landfilled (Sakai & Hiraoka 2000). Consequently, looking for ways to utilise MSW ash is thoroughly researched. Demonstration tests have confirmed the proven technology of the incinerated ash melting and stone production process, the durability of the plant, and the safety and stability of produced stones (Nishida *et al.* 2001). Nishida *et al.* (2001) are convinced that this technology will contribute to the environmental protection and be a beneficial use of resources.

2.2.7 Disposal

The largest, human-made structure on the planet is not an Egyptian pyramid, nor a hydroelectric dam, but the Staten Island Fresh Kills landfill near New York City, which has a depth of one hundred meters and an area of nine square kilometres. It is even larger than the Great Wall of China, and is so large it can be seen with the naked eye from space. (Homer-Dixon 2000.)

As the last, in virtually every waste management hierarchy, stands disposal. Landfill, or 'final storage' as it is sometimes referred to, critically viewed, seems like a very careless solution: dump it and cover it; out of sight, out of mind. In reality, a modern landfill, with its carefully designed shape, size and location, geo-synthetic liners and capillary barriers, leachate and landfill gas collection equipment and monitoring system, is a carefully engineered entity.

Landfill technology at its best is highly advanced and thoroughly researched. However, large amounts of material are entombed below the surface, producing methane, which is up to 60 times greater than CO₂ in its contribution to global warming; and leaking leachate, containing potentially toxic compounds. Another fact is that the basic materials hidden in landfills constitute a rather high monetary value. Disposal, however, does only not mean landfill (see Table 6). It also includes thermal destruction, which in some cases may actually be the best option for neutralising hazardous waste. Notwithstanding, the European Communities (1999) maintain that both disposal and incineration are potentially harmful to the environment and to human health.

Despite the environmental drawbacks of landfill, most European municipal and hazardous waste is disposed of into or onto land. Since landfill is likely to remain a disposal option for part of our waste, it is important that it is carried out to the highest standards in the effort to protect human health and the environment.

The common misperception is that materials, such as paper and food, biodegrade once put into landfills. The fact is that these materials need moisture and air to biodegrade. Under anaerobic conditions within a landfill site, slow stabilisation of the waste mass occurs, producing methane and leachate over long periods of time. As a potential solution, with a technology called Aerobic Landfill System (ALS) it was demonstrated that the aerobic degradation of MSW within a landfill can significantly increase the rate of waste decomposition and settlement; decrease the methane production and leachate leaving the system, and potentially increase the operational life of the site. Readily integrated into the existing landfill infrastructure, this approach can safely, and cost-effectively, convert an MSW landfill from anaerobic to aerobic degradation processes,

thereby effectively composting much of the organic portions. (Read *et al.* 2001.) In ALS, moisture (leachate) and air are introduced into the landfill. Instead of anaerobic decay and methane production, respiring indigenous micro-organisms under aerobic conditions rapidly covert organic material into carbon dioxide, water, and salts, as observed in typical composting operations, thereby methane and anaerobic odour production is minimal. During a 24- to 36-month operational period, rapid waste stabilisation will occur, with waste mass temperatures naturally rising to and controlled near 74°C. This elevated temperature evaporates much of the waste moisture and added leachate. (Hudgins & March 1998.) As demonstrated at landfills in the U.S.A., Japan, and Europe, results from previous ALS's have shown to rapidly stabilise landfilled wastes for more suitable mining while, at the same time, reducing the cost burdens of landfill operations and/or site remediation. Despite the uniqueness of each landfill and waste characteristics, the following benefits were observed (Hudgins & Harper 1999):

- rapid and safe degradation of the organic matter in the landfill;
- reduction in leachate contaminants and volumes;
- reduction of methane and malodorous gases emissions;
- increased waste settlement.

Through the continued development of this technology, Aerobic Landfill System offers a new prospective for landfilling of waste.

3 Waste management legislation

"If you are not confused, you are not up-to-date." - Unknown

The problem of waste can be viewed in various ways. At one level, it simply constitutes a significant source of pollution. As Alexandre Kiss put it, in the widest sense, a major proportion of pollution consists of introduction into the environment of substances of which one wishes to rid oneself (cited in Tromans 2001). This represents the original justification for regulating waste disposal, and continues to constitute a compelling reason to do so (Tromans 2001). It is, still, largely the case that the rules of international laws are, with few exceptions, aimed at regulating the disposal of waste rather than addressing and preventing its generation. However, regulating disposal can only go so far in "limiting the avalanche of waste which is now threatening to engulf industrialised countries" (Sands 1995). Consequently, attention has shifted, at least at national and EC levels, toward policies and legislation designed to minimise the generation of waste and to secure its beneficial re-utilisation (Tromans 2001). Viewed in this sense, some argue that waste disposal can be viewed as the ultimate reintroduction or reintegration of substances which have originally been extracted from the environment, back into the environment from whence they came (Campbell-Mohn *et al.* 1993).

3.1 The European Union policy on environment

Protection of the environment is one of the major challenges facing Europe. The European Community has been strongly criticised for putting trade and economic development before environmental considerations. Community action developed arbitrarily over the years, until the Treaty of European Union conferred upon it the status of policy.

Within the European Commission, Directorate General XI used to be responsible for Community policies for the environment, nuclear safety and civil protection. Its actions are carried out within the strategy defined in 1992 by the European Community Fifth Programme of Policy and Action in Relation to the Environment and Sustainable Development "Towards Sustainability" (European Council 1998).

The appointment of a new Commission in September 1999 was accompanied by a reorganisation of the Commission administration. There are now 36 departments and directorates-general are no longer referred to by number. Directorate E of Industry and Environment oversees, among others, waste management.

The range of environmental instruments available has expanded as environmental policy has developed. The Community adopted framework legislation providing for a high level of environmental protection while guaranteeing the operation of the internal market. It has introduced a financial instrument: the Life Programme, and technical instruments: eco-labelling, the Community system of environmental management and auditing system for assessment of the effects of public and private projects on the environment.

The Sixth Environment Action Programme defines the priorities and objectives of Community environmental policy up to 2010 and beyond, and describes the measures to be taken to help implement the European Union's sustainable development strategy (Commission of the European Communities 2001). The programme has been guided by the Fifth Environment Action Programme (European Council 1998). The Sixth Environment Action Programme focuses on four priority areas for action: climate change; biodiversity; environment and health; and sustainable management of resources and wastes. The objective is to ensure that the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment, and to achieve a decoupling of resource use from economic growth, through significantly improved resource efficiency and the reduction of waste. With regard to waste, the specific target is to reduce the quantity going to final disposal by 20% by 2010, and 50% by 2050.

The actions to be undertaken are as follows (Commission of the European Communities 2001):

- The development of a strategy for the sustainable management of resources by laying down priorities and reducing consumption;
- The taxation of resource use:
- The removal of subsidies that encourage the overuse of resources;
- The integration of resource efficiency considerations into integrated product policy, eco-labelling schemes, environmental assessment schemes, *etc.*;
- Establishing a strategy for the recycling of waste;
- The improvement of existing waste management schemes and investment in quantitative and qualitative prevention;
- The integration of waste prevention into the integrated product policy and the Community strategy on chemicals.

3.2 Waste legislation in the European Union

To date, European action in the waste field has mainly taken the form of legislation. Other measures supported by the EC to improve the European waste situation include technical research, recycling industries, training, awareness-raising actions and exchange of good practices. While these actions have prevented the situation from becoming even

worse than it is today, waste generation is still too high and is rising annually. For years, there has been too little action on the European waste problem and inadequate planning for an optimal solution. As far back as 1975, Community legislation required Member States to develop comprehensive waste management plans, and 25 years on, little has progressed. The situation within the EU regarding waste management continues to be unsatisfactory. (European Communities 1999.)

Protection of the environment and natural resources has steadily grown since the 1980s. As a result, measures ranging from legislation, financial instruments, *etc.* has been undertaken, especially at the European level. The reason for the interest in waste management is the fact that the EU generates, annually, approximately 1 300 million tonnes of waste, from which an estimated 23,5 million is classified as hazardous. Municipal waste in OECD countries increased by about 11% between 1990 and 1995, to a total of around 200 million tonnes. Forecasts point to continued increases in the near future. There is no blueprint which can be applied in every situation, but the EU has firm principles upon which its approach to waste management is based. These include (European Communities 1999):

- Prevention principle waste production must be minimised and avoided where possible.
- Producer responsibility and polluter pays principle those who produce the waste or contaminate the environment should pay the full costs of their actions.
- Precaution principle we should anticipate potential problems.
- Proximity principle waste should be disposed of as closely as possible to where it is produced (the goal of which is to prohibit waste transport to, and disposal in countries with lower environmental standards).

European institutions have taken a number of steps. The most important regulations are summarised in Table 7

Table 7. The most important waste-related regulations in the EU.

Council Directive on Waste 'Waste Directive' (European Council 1991a)	The 'Framework Directive' on waste, provides definitions of the most important concepts, and sets out categories of waste in its Annex I.
The Regulation on the supervision and control of transfrontier waste shipments (European Council 1993)	The regulation sets out controls for the shipment of waste. The penalties for illegal trafficking are left to member states' responsibility.
The Directive on Packaging and Packaging Waste 'Packaging Directive' (European Council 1994)	The Directive sets targets for recovery and recycling and proposes that a marking scheme for packaging be set up. It requires that 50-65w% of the packaging waste shall be recovered. Within this, 25-45w% of packaging materials shall be recycled, with a minimum of 15w% for each material.
The EC Directive on Integrated Pollution Prevention and Control 'IPPC Directive' (European Council 1996)	The purpose is to achieve integrated prevention and control of pollution arising from activities listed in Annex 1 of the Directive, through permits to be issued by the Member States. The Polluting Emissions Register (PER) inventory is required to be to reported in 2002. The results of the European PER would be fed into the Integrated Emissions Inventory (IEI).

Table 7. (Continued)

The Directive on the Landfilling of Waste 'Landfill Directive' (European Council 1999)	Adopted on April 27, 1999, divides landfills into three classes (landfill for hazardous, non-hazardous, and inert waste) and provides for the first time common requirements for all 15 Member States. One significant element is the requirement of drastic reduction of biodegradable waste going to landfill: to 75w% by 5 years, 50w% by 8, and 35w% by 15 years.
Directive on End-of-Life Vehicles (European Council 2000c)	This Directive of September 18, 2000, prescribes that Member States should ensure that the last holder and/or owner can deliver the end-of life vehicle to an authorised treatment facility without any cost as a result of the vehicle having no or a negative, market value.
Proposal for EC Directives on Waste Electrical and Electronic Equipment and on the restriction of the use of certain hazardous substances in electrical and electronic equipment (European Council 2001d)	Main areas of the proposal adopted on June 13, 2000, were: separate collection goals to be met by January 1 st , 2006; responsibility for the treatment and recovery of WEEE is placed on the producer; specific recovery rates are to be met by January 1 st , 2006; Hazardous Substances proposal requires the substitution of Pb, Hg, Cd, Cr VI, and certain flame retardants (PBB, PBDE) by January 1 st , 2008.

In Europe in the area of pollution control, three different approaches can be distinguished: technical descriptions, emission standards and quality standards (Lübbe-Wolff 2001). The efficiency of economic instruments and command and control regulation is often contrasted. Lübbe-Wolff adopts the premise that management by objectives is generally more efficient than detailed prescription. Judgements about the comparative efficiency can be made. Although the European IPPC Directive uses language referring to technical standards, it does not follow that it is based on technical descriptions. What is agreed, is that common terminology and a definition of waste are needed in order to improve the efficiency of waste management in the Community. The definitions of Council Directive 91/156/EEC of March 18, 1991 amending Directive 75/442/EEC on Waste, Article 1, are collected in Table 8.

The Waste Directive states in its Article 3 (European Council 1991a) that Member States shall take appropriate measures to encourage:

Firstly: the prevention or reduction of waste production and its harmfulness by:

- a) the development of clean technologies more sparing in their use of natural resources;
- b) the technical development and marketing of products designed so as to make no contribution or to make the smallest possible contribution, by the nature of their manufacture, use or final disposal, to increasing the amount or harmfulness of waste and pollution hazards;
- c) the development of appropriate techniques for the final disposal of dangerous substances contained in waste destined for recovery.

Secondly:

- a) the recovery of waste by means of recycling, re-use or reclamation or any other process with a view to extracting secondary raw materials,
- b) or the use of waste as a source of energy.

Table 8. Definitions provided by Council Directive 91/156/EEC on Waste (European Council 1991a).

Waste	shall mean any substance or object in the categories set out in Annex I (Table 16) which the holder discards or intends or is required to discard.
Producer	shall mean anyone whose activities produce waste ("original producer") and/or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.
Holder	shall mean the producer of the waste or the natural or legal person who is in possession of it.
Management	shall mean the collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites.
Disposal	shall mean any of the operations provided for in Annex IIA (Table 6).
Recovery	shall mean any of the operations provided for in Annex IIB (Table 4).
Collection	shall mean the gathering, sorting and/or mixing of waste for the purpose of transport.

Furthermore, Article 4 of the Waste Directive sets out that "waste shall be recovered or disposed of without endangering human health and without using processes or methods which could harm the environment", and in particular:

- without risk to water, air, soil and plants and animals;
- without causing a nuisance through noise or odours;
- without adversely affecting the countryside or places of special interest.

Waste management policy is fast becoming a major social and political issue internationally. However, little work, until now, has been carried out on the ways in which local governments are responding to the new waste management agendas (Read 1999a). To date, it is apparent that local practices bear little resemblance to national ideals or strategy, and that the different tiers of waste management authority that are currently in operation do little to help the situation because of their own agendas and responsibilities, effectively blocking opportunities for collaboration and partnership in service development and delivery.

Local waste management practices are clearly a response to a number of key parameters operating on a local authority. These include: availability of landfill, relative costs of MSW management options, funding and staffing levels (political bias), and historical trends in the management of waste (existing markets and processing facilities). The study by Read (1999a) shows that 40% of authorities in England are experiencing a policy implementation gap, with 70% claiming to suffer from local implementation failure, with costs of options, staffing levels, local government cut-backs and the introduction of privatisation being cited as the key reasons for failure.

3.3 Waste legislation in Finland

The Waste Management Act (Valtioneuvosto 1978), which came into force in 1979, was the first act in Finland dealing specifically with waste management. After Finland joined

the European Economic Area in 1994, and the European Union in 1995 the waste legislation had to be reformed to bring it in line with corresponding European Community legislation. The new Waste Act (Valtioneuvosto 1993a) and Waste Decree (Valtioneuvosto 1993b), which came into force on January 1st, 1994, implementing the provisions of Council Directive on Waste (European Council 1991a) on hazardous waste, and Council Regulation on the supervision and control of trans-frontier shipments of waste (European Council 1993).

Compared with the earlier Waste Act, the new Act emphasises more preventive measures for minimising the waste generated and diminishing the harmful properties of waste. The Act also requires the recovery of waste if this is technically and economically feasible, primarily in the form of materials and, secondarily, as energy.

Both Finland and the EU apply the principle of producer responsibility to minimise the generation and to enhance the recovery of certain types of waste. This principle was first incorporated into Finnish law through the Government decisions on discarded tires (Valtioneuvosto 1995b), packaging and packaging waste (Valtioneuvosto 1997) and waste paper (Valtioneuvosto 1998a).

The Waste Act also committed the environmental authorities to setting up national and regional waste plans. The regional waste plans had to be prepared by 1996, and the National Waste Plan came into effect in August 1998 (Ministry of the Environment and the Finnish Environmental Institute 1999). The authorities in charge of the implementation of the Waste Act and National Waste Plan are (Ympäristöministeriö 2002a):

- The Ministry of the Environment: supervision and control over the enforcement of the legislation.
- The Finnish Environmental Institute: conducting research and training, giving out practical information, and monitoring the development related to waste issues, also participating in preparation of legislation.
- Regional environment centres: guiding, encouraging and monitoring the implementation of the Waste Act on the regional level, issuing permits to large firms and operations.
- Local authorities: organising the collection, recovery and disposal of household refuse, issuing waste permits to small firms, setting local regulations etc.

The National Waste Management Plan had prescribed that, by the year 2000 the recovery rate of municipal waste will have had to have been at least 50%, and the number of landfills not more than 200. In addition, the management of landfills will have had to have been improved considerably. Other wastes ought to have been recovered as much as it is technically and economically feasible. As well, by the year 2005, the recovery rate of 70% will have been exceeded. In 1994, the reference year of the Plan, 2.1 million tonnes of MSW was produced, of which 30%wt was recovered (Ministry of the Environment 1998). Recovery and disposal of waste is summarised in Table 9.

As stated earlier, there are no comprehensive data for all waste types for one and the same year. The information in Table 9 is compiled from different sources and refers to different years and is to some extent based on statistical and calculated values, and they are not, as such, comparable with international levels. The data on the total amount of mining wastes is given based on dry solid content. The total effects of the steps suggested in the Waste Plan would be that in 2005, waste amounts and recovery levels would be shown as summarised in Table 10.

Table 9. Recovery and disposal of wastes in Finland (Ministry of the Environment 1998).

Waste group	Total waste (million t/a)	Recovered amount (million t/a)	Recovered amount (%)	Disposed amount (million t/a)	Disposed amount (%)
Mining waste	15	-	-	-	-
Agricultural waste	22	18,7	85	3.3	15
Industrial waste	15.4	9.1	59	6.3	41
Construction waste	8	0.7	23	2.3	77
Wastes from energy and water supply	3	0.7	23	2.3	77
Municipal waste	2.1	0.6	30	1.5	70
Sewage waste	1.5	0.8	53	0.7	47
Hazardous waste	0.5	0.1	20	0.4	80
Total wastes	67.5	-	-	-	-
- excluding mining waste	52.5	32.3	61.5	20.2	38.5
- excluding mining waste and manure utilised in agriculture	30.5	13.6	44.5	16.9	55.5

Table 10. Forecasted recovery of waste in 2005 according to the Waste Plan (Ministry of the Environment 1998).

Waste group	Total waste amount without waste reduction measures (mil- lion t/a)	Total waste amount after waste reduction measures (million t/a)	Recoverable amount (million t/a)	Recoverable amount (%)
Mining waste	15	15	-	-
Agricultural waste	22	22	19.8	90
Industrial waste	15.4	19	13.3	70
Construction waste	8	7.1	5	70
Wastes from energy and water supply	3	3.2	1.6	50
Municipal waste	2.1	2.1	1.5	70
Sewage waste	1.5	1	0.7	70
Hazardous waste	0.5	0.4	0.2	50
Total wastes	67.5	69.8	=	-
- excluding mining waste	52.5	54.8	42.1	76.8
- excluding mining waste and manure utilised in agriculture	30.5	32.8	22.3	68

In order to guarantee high-level and sufficient recovery and disposal capacity for all types waste, in accordance with the self-sufficiency and the proximity principle, a network of disposal and recovery sites for municipal waste and hazardous wastes would be developed by the year 2005. They are summarised in Table 11.

Table 11. Waste management infrastructure as targeted by 2005 (Ministry of the Environment 1998).

Disposal and recovery sites	Situation in 1996	Situation in 2005
Bio-waste plants or sites for centralised biological recovery or disposal	17	40-50
Power plants using waste-derived fuel, and the Turku incineration plant	3	15-20
Landfills for municipal waste	390	50-80
Hazardous waste recovery and disposal sites	75	50-60
Contaminated soil disposal sites	30	60

The City of Oulu is located in the North Ostrobothnia region of Finland. North Ostrobothnia's Waste Act was accepted in 1996 (Rinta-Jaskari 1996). However, Paragraph 17 of Finland's Waste Act (Valtioneuvosto 1993a) states that, based on the general clauses of this Act, local authorities can define their own regulations on waste collection, separation, storage, transport/transfer and treatment, and the related technical requirements. According to the Environmental Office of the City of Oulu, in 2000 the Bureau made the best of this opportunity and decided to renew its waste regulation (Personal Communication 17.04.2002). Oulu's newest Waste Decree has been operational since May 1st, 2000. It advocates separate waste collection. Finland's Waste Act also prescribes that the collection of waste is the responsibility of the producer. However, owners of housing complexes are responsible for organisation of the collection and removal of waste. In this case, the producers of the waste - the tenants - will bring their waste to the site provided by the housing owners (Valtioneuvosto 1993a). Thus far, citizens in Oulu have been able to bring recyclables to recycling points (ekopiste). Now housing in Oulu, with at least four apartments, must provide separate waste collection containers, besides mixed waste, for paper waste and bio-waste. For housing with at least ten apartments, additional containers are to be supplied for liquid board and cardboard packaging. Other real estate, such as office complexes, small business, industrial, or educational institutions, and restaurants should provide containers for (Oulun kaupunki 2000):

- paper waste;
- bio-waste if there's a cafeteria on the premises;
- paperboard, if the generation is at least 20 kg/week;
- glass waste, if the generation is at least 20 kg/week;
- wood waste, if the generation is at least 20 kg/week;
- metal waste, if the generation is at least 200 kg/year

When planning this Decree, the Environmental Office of the City of Oulu utilised the experiences of larger cities, such as Helsinki, Tampere and Jyväskylä. Therefore, while it is not surprising that, though globally, urbanisation involves one of the biggest environmental problems, in Finland, the environmental problems of cities are handled more successfully than those of the countryside (Ojala 2000). This is also due to the fact that the population density in Finland is low (17 people/km²) and there are no 'megacities' in Finland: Helsinki, the capital, has a population of 540 000 people. In addition, while 80% of the European Union's population live in urban areas (European Communities 2000), in Finland, only 63.9% live in urban areas (OECD 1999). Finally, Finland sets great store upon environmental protection. As a result, a recent Environmental Sustainability Index study for 142 countries ranked Finland first in overall progress toward environmental sustainability (GLT 2002).

The City of Oulu had organised the mapping of waste collection receptacles, and had found that by March 2001, 87% of examined housing had the required separate waste collection containers (Oulun kaupunki 2001). The results of Oulu's new waste decree can be viewed by the change in the amount of collected recyclables as illustrated in Table 12. While the total amount of collected waste has decreased, the amount of collected paper nearly doubled, the amounts of bio-waste, metals and paperboard (consisting mainly of packaging cartons) increased, while the amount of glass and cardboard has not changed considerably. The reason for this could be that glass bottles are returned for deposit, and cardboard is mainly used for secondary packaging, thus they are collected from shops rather than housing.

Table 12. Recyclables collected (kilograms) in Oulu in 1999 and 2001 (Suppanen 2000, Suppanen 2002).

	MSW	Paper	Paperboard	Cardboard	Glass	Metal	Plastic	Bio-waste
2001	48 300	682 440	73 120	13 720	416 245	262 879	76 720	4 684
1999	52 203	348 700	64 880	14 980	471 370	122 410	87 850	3 779

Bio-waste is to be transported to composting facilities approved by environmental authorities, or is to be composted *in situ*. The other recyclables are to be directed to the appointed receiving facilities. The above-mentioned smaller residence real estate also have to deliver their recyclables to the local waste transfer stations. The separate collection obligation also applies to public gatherings.

The packaging waste production of Finland in 1999 was 442 600 tonnes, of which roughly 60% was recovered. The per capita amount of packaging waste is relatively low due to the high re-usage rate of packaging waste: 64% (see Table 13).

Table 13. Re-use of packaging in Finland as percentages of total use (PYR 2002).

Year	Fibre	Glass	Metals	Plastics	Total
1994	-	87	14	59	56
1997	5	87	86	69	64
1998	5	85	90	70	66
1999	4	83	90	69	64

The large, positive change in re-use of metal packaging is mainly due to a change in the types of packaging included in the statistics. The figures for 1997 include certain items required by EU regulations such as dairy containers, wire trolleys and beer packaging. These were not included in the statistics for 1994.

Finland is one of the leading countries in Europe in the re-use of packaging. The glass re-use rate alone was 83% in 1999 (see Table 13). The first formal eco-tax in Finland was levied on beverage containers in 1976 (Hagelstam 2001). According to the present provisions, a supplementary tax must be paid for beverages, beer and other alcoholic drinks, when there is no recovery of packaging waste (Ympäristöministeriö 1994). Aluminium cans, cardboard and liquid board containers have been recycled for years and, consequently, the average packaging-recycling rate is 50%. As Table 14 shows, the overall recycling targets for 2001 were already reached by 1999 (PYR 2002).

Table 14. Recycling of packaging materials as percentage of total packaging waste in Finland (PYR 2002).

Year	Fibre	Glass	Metals	Plastics	Total
1994	44	38	4	1	30
1997	57	48	8	10	42
1998	57	62	16	10	45
1999	61	78	19	13	50
2001 target	53	48	25	15	42

The target percentages for 2001 are agreed upon by Finland with the EU

3.4 The effects of legislation

For over ten years, the Community Strategy on Waste has recommended the hierarchy of principles. An appropriate question therefore is, has the Community made progress towards meeting the principles of this Strategy? (Christiansen 1999.)

In relation to waste prevention, the general trend has been an increasing amount of waste and the goal is far from being attained. This does not mean that it is impossible to demonstrate with situations where waste prevention has taken place, but it has not been to such an extent that stabilisation or reduction of waste quantities has resulted.

Due to lack of sufficient and reliable data, it is difficult to evaluate the extent to which recovery has replaced disposal. For some countries, it is possible for the total waste generation to identify an increase in recycling and a reduction in landfilling for the period 1985-1995. However, for many countries, landfilling is still the most common treatment method. Figure 5 exhibits trends in treatment of MSW in the 18 EEA member countries.

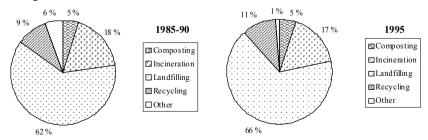


Fig. 5. Development in disposal and treatment of municipal waste in EEA member countries (European Topic Centre on Waste 1999).

As stated earlier, although there has been an increase in the level of recycling, landfilling still remains the most widespread treatment, and was at the same level in 1995 as in 1985-90. In the same period, there was an increase in the amount of municipal waste landfilled from 81 million tonnes to 104 million tonnes. Even if a part of this increase may be due to better registration, it is then reasonable to conclude that, in absolute figures, the EU countries landfilled more municipal waste in 1995 than in the period 1985-90. (Christiansen 1999.) The challenge of reducing the quantities of waste as such cannot be solved in a sustainable way by efficient waste management and recycling alone. There is an urgent need for integration of waste management, and into a strategy for sustainable development and into a number of related policy areas, where reduction of resources depletion, energy consumption and minimisation of emissions at the source are given high priority. Waste must be analysed and handled as an integrated part of total material flow through society. As the European Community programme of policy and action in relation to the environment and sustainable development demands, the following practical requirements are necessary for achieving sustainable development (European Council 1993b):

- Since the reservoir of raw materials is finite, the flow of substances through the various stages of processing, consumption and use should be so managed as to facilitate or encourage optimum re-use and recycling, thereby avoiding wastage and preventing depletion of the natural resource stock;
- Production and consumption of energy should be rationalised; and
- Consumption and behaviour patterns of society itself should be altered.

De-linking of waste generation from economic activity has a key role in helping to meet the objectives of reduced waste generation. Waste production is influenced both by how efficiently we use resources in production, and the quantity of goods we produce and consume. In Fig. 6, for each Member State, the waste quantity/capita has been plotted against the economic activity related to the selected waste streams. (Christiansen 1999.)

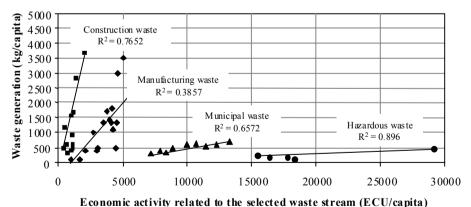


Fig. 6. Municipal waste, construction waste, manufacturing waste and hazardous waste in EU in 1995 in relation to economic activity (Christiansen 1999).

A closer analysis of the relation between economic growth and waste generation does reveal several different trends. According to Fig. 6, the generation of municipal,

construction and hazardous waste seems to relate to the economic activity behind waste generation whereas such a relation does not appear to be exact for manufacturing waste. The amount of waste generated in European countries belonging to the OECD increased by an estimated 10% between 1990 and 1995, while GDP increased by 6.5% (European Environmental Agency 2000). As shown in Fig. 7, it cannot be said that great successes were achieved in the 1990s in de-linking municipal waste from household expenditure.

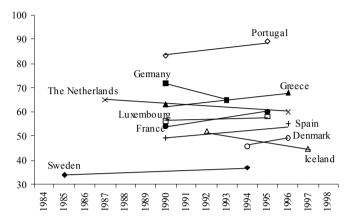


Fig. 7. Municipal waste generation compared with household expenditure in selected EEA member countries, 1984-1998 (European Topic Centre on Waste 1999).

The Environmental Signals 2000 report (European Environmental Agency 2000) suggests that for the future, priority needs to be given to construction and manufacturing waste and waste transport. Transport of waste is a growing concern, since transport distances are also much higher for waste recycling than those for disposal. The report quotes a French study by Ripert (1997), which suggests that 15% of all freight transport involve waste, and that waste transport accounts for 5% of the transport sector's total energy consumption. The environmental pressures caused by transport are likely to increase in the future as waste is separated into more segments for different treatment.

3.4.1 Recycling in Finland

A case study, based on distributed and completed questionnaires, conducted at Jyväskylä University in Finland, examined the realisation of waste management in local communities (Urpilainen & Hänninen 2000). The questionnaires revealed that local authorities find glass recycling the most problematic, due to its relatively low retail value, contrasted with high collection, transport and treatment costs. In North Ostrobothnia, up until 1994, the Ahlström Oy factory in Ruukki took collection of waste glass (Rinta-Jaskari 1996). After this factory shut down, local authorities still collected the glass, which was mainly stored in hopes of some future use (Suppanen 2000). Glass is still perceived as *the* symbol of recycling (Urpilainen & Hännine 2000). The glass industry used to claim that every tonne of cullet used in the manufacture of new glass saves the

equivalent of 136 litres of oil. However, according to the British Glass Recycling Company, only 32 litres savings is attributable to manufacturing, the rest goes for extraction and transport (Tickell 1993). The remaining 104 litres are thus saved only for the industry, not for the environment. Presently, cullet is increasingly being used for other applications than glass manufacturing purposes. Recently, the Rusko Area Waste Station in the City of Oulu started to use cullet for building bio-gas wells, thereby replacing gravel (Suppanen 2002).

Cardboard collection was also seen as expensive due to its high volume *versus* low weight. This was particularly apparent in sparsely populated areas, where transportation distances are great between collection points. On the topic of plastics recycling, it was observed that, while Finnish citizens are eager to recycle plastics, local authorities perceived plastics recycling as problematical to realise due to difficulties in separating different types of plastics. (Urpilainen & Hänninen 2000.) A survey of developmental needs in waste management by the Technological Research Centre of Finland, VTT, also concluded that the realisation of plastics recycling is meaningful to realise only within the industry, but not when plastic waste is collected from municipalities (Anhava *et al.* 2001).

Paper waste has been collected in Finland since the 1920s, and official, organised collection was started in 1983, when Paperinkeräys Oy was established (Paperinkeräys Oy 2001a). In Finland, waste paper collection is based on the Polluter Pays Principle, and is enforced by law (Valtioneusvosto 1998b). The paper producers of Finland have appointed Paperinkeräys Oy to treat and utilise the collected waste paper (Paperinkeräys 2001a). Accordingly, paper-collection is organised and practised throughout the country. One can find paper collection bins even in the most remote spots of Finnish Lapland. In 2000, the paper recovery rate of Finland was 67% (Fig. 8).

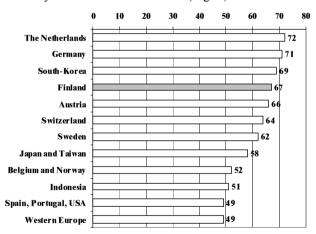


Fig. 8. Paper recovery in selected countries (%) in 2000 (Paperinkeräys 2001b).

According to the Information Officer of Paperinkeräys Oy (Personal Communication 15.04.2002), given that the paper consumption in 2001 has slightly decreased overall, the recovery rate has increased to 74%. The collected paper and board products are transported, by types, to the appropriate facilities. In the year 2000 they were utilised as illustrated in Fig. 9.

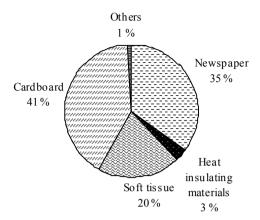


Fig. 9. Use of recovered paper as raw material in Finland in 2000 (Paperinkeräys 2001a).

As the map in Fig. 10 will show, most of the paper and board companies that use waste paper as raw material are located in the Southern area of Finland.

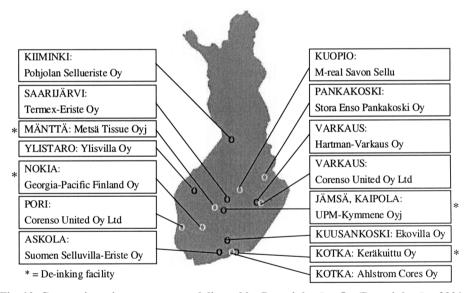


Fig. 10. Companies using waste paper delivered by Paperinkeräys Oy (Paperinkeräys 2001a).

Housing companies, even in Lapland, are pleased to participate in paper collection because, by doing so they save on the waste tax, given that contributing to paper recovery is cheaper than sending to landfill (Portti & Koivula 2001). While in the town Kiiminki (approxiately 25 km northeast of Oulu), the factory appears to be ideally situated for accepting waste paper collected from the northern part of the country, they can use only the highest quality paper. According to the Oulu unit of Paperinkeräys Oy (Personal Communication 12.04.2002), they mostly process mackle paper of a nearby printing plant as well as white office paper and pure newsprint. Whereas the mixed paper from

households - newsprint, magazines, commercial flyers, envelopes - can only be processed by the factory in Kaipola (approximately 400 km south of Oulu). A small, local waste collection company, Ekotuote, that services only 3 housing complex proprietors in Oulu city has decided to separate mixed paper, and sell the newsprint to the Kiiminki plant. According to Ms. Tytti Tuppurainen, the spokesperson of the Ekotuote company (Personal Communication 02.07.1999), this solution is profitable for them, given the higher value of newsprint. However, this solution could not be used throughout North Ostrobothnia and Lapland because the Kiiminki plant can accept only limited amounts of waste paper. Waste paper from North Ostrobothnia and Lapland thus continue on to Kaipola. Given that there is country-wide, organised waste paper collection, which is mainly run by one company, and with the economic incentives, it is not surprising that Finland has achieved high recovery rates, despite the scarce population. According to the head of the Finnish forestry industry concern, Metsäteollisuus Oy, the reason for the success is threefold: the enthusiasm of Finns to recycle, developments in papermaking technology, and the market of the recycled paper that supports the transportation network (Tiilikainen 2002). As well, de-inking waste produced during the refining of waste paper is exempt from the landfill tax (Valtioneusvosto 1998b). Nevertheless, one cannot help thinking: could the price of this success be too high?

Byström and Lönnstedt (1997) have studied the environmental and economic impact of paper recycling in Scandinavia, and found no evidence that increased recycling of products, based on chemical pulp, is an environmentally-friendly policy. They argue that processing waste paper and paperboard is usually derived from fossil fuel, while production of 'virgin-based' chemical pulp yields a thermal surplus, which waste paper processing does not. Thus, if waste paper is recovered for energy purposes, the need for fossil fuel would be reduced, resulting in a favourable impact on the carbon dioxide balance and the greenhouse effect. (Byström & Lönnstedt 2000.)

A study in the U.S.A. on greenhouse gas emissions from municipal waste management, came to the same conclusion, and argues that when paper products are recycled, trees that would otherwise be harvested are left standing. In the short-term, this results in a larger amount of carbon remaining sequestered, because the standing trees continue to store carbon, whereas paper production and use tends to release carbon. However, in the long-term, as reducing need of trees results in less planting of new, managed forests, there will be less forest acreage covered with rapidly-growing trees, and thus rapidly sequestering carbon. In brief, they found a relationship between paper recycling and carbon sequestration: recovery of one ton of paper results in incremental forest sequestration of 0.73 tons of carbon equivalent. (ICF 1998.)

3.5 Challenging the solid waste management hierarchy

As a critic of the waste management hierarchy, Kirkpatrick (1992), believes that decisions over the relative merits of waste management options are determined largely by economic and logistic factors, demands of legislation, concerns over the availability of landfill space, and the desire to adopt more effective resource management practices. He

argues that the order of alternative waste management options depends on the relative importance attached to different environmental considerations.

Solid waste management is only one facet of the environmental debate, Kirkpatrick explains. Environmental impacts do not only occur when materials have served their useful purpose and thence become waste. It is only by an examination of all environmental impacts over the complete life cycle of a given product, for example by using Life Cycle Analysis, that one begins to place the issue of solid waste management in context. On the contrary, he believes the present hierarchy was determined on the basis of a common sense approach, focusing on considerations of resource conservation and optimisation of the use of raw materials.

3.5.1 What is wrong with recycling?

The word 'recycle' is originally derived from the natural cycles of water or carbon. In the sense of these complete (closed) and permanent cycles, recycling of manufactured articles does not take place. It would hardly be possible to convert metals to the iron ore from which they were originally made and scatter this in the mine. Equally, glass is not, and never will be, recycled to sand and limestone; nor plastics to crude oil and re-injected into a well. Cellulose products are probably the only materials that may be recycled in the true sense of the word within the human life-span. If incinerated, or otherwise oxidised to CO₂ and water, they re-enter the global carbon and water cycles, eventually being absorbed by vegetation. In time, biodegradable plastics made from natural, raw materials can, in a similar fashion be recycled. For example, a starch-based biopolymer composted and the compost used on corn plantations. (Katan 1987.)

Recycling actually only occurs once the secondary material has been converted into a new product, or is utilised in another way. Thus, the availability of markets for the secondary materials generated is fundamental to the success of recycling. This is principally the role of industry who must ensure the continuing availability of processing facilities to match the increasing amounts of secondary materials that will be recovered.

Nevertheless, Gertrude Lübbe-Wolff, a professor of Environmental Law, points out that waste management produces external costs that are not included in product prices. Take-back obligations force producers to deal with the problems they create and do not just leave it for society's care (Hanisch 2000). Extended Producer Responsibility (EPR) was initiated by the German Packaging Ordinance, the famous Duales System Deutschland (DSD), in 1991. Hanisch quotes that, at that time, Germany faced a severe landfill shortage, with packaging waste amounting to a significant percentage – 30% by weight and 50% by volume – of the nation's total municipal waste stream. This reasoning, however, conveniently fails to mention what percentage of municipal solid waste constituted of all solid waste in Germany in 1991, what percentage of all waste ended up in landfill and, ultimately, what percentage of packaging waste was constituted in landfills. As a case in point, in Finland, municipal solid waste was estimated to constitute a mere 3% of all wastes (Ministry of the Environment 1998). According to Table 9, excluding mining waste and manure utilised in agriculture, 16.9 million tonnes of waste was disposed, out of which municipal waste was 1.5 million tonnes, which constitutes

8.9% of the total. At the same time, 57% of all packaging waste was estimated to be landfilled (PTR 1996). If the percentage of packaging waste in municipal waste was 30% (0.45 Mt), of which 57% was landfilled (0.2565 Mt), packaging waste would constitute approximately 1.5% of all landfilled waste. Viewed in such a context, packaging waste does not appear to be overflowing landfills.

According to Rathje and Murphy (1992), the claim that packaging waste is a major constituent in landfills is simply a myth. Over a period of five years in the U.S.A., their "Garbage Project" excavated 14 tons of waste from nine municipal landfills. This project sought to address the claim that fast-food packaging and polystyrene foam were the major elements of American trash. They found that out of the 14 tones of excavated waste, 1% was polystyrene foam, and less than 0.5% was fast-food packaging. (Rathje & Murphy 1992.)

Despite this evidence, in Europe, the 'packaging waste myth' of the early 1990s ultimately led to the Packaging Waste Directive in 1994. Eventually, according to a year 2000 estimate, all the EU Member States were to comply and achieve the Directive's general target of 25% recycling. Plastic was the only material for which, in several countries, the recycling quotient was below the 15% minimum recycling rate set by the Directive. The 15% recycling rate for plastic was exceeded only by Germany and Austria, although The Netherlands, Italy, Sweden and Finland were not far behind in achieving this rate as well. (Hanisch 2000.) According to the Environmental Register of Packaging (PYR 2002), by 2001 Finland will have had achieved the 15%-minimum recycling rate of plastics (see Table 14).

Hanisch cites Hans-Peter Oels, a packaging expert of the German Federal Environmental Agency, who says that between 1991 and 1998, the per capita consumption of packaging waste was reduced from 94.7 kg to 82 kg/capita, that is, by 13.4%. Oels concluded that, since Germany is consuming less packaging with rising economic growth, the goal of waste reduction has been achieved. However, Bette Fishbein reminds us that, while the Packaging Ordinance did reduce packaging and increased recycling in Germany, it did so at a high cost: in 1998 DSD spent DEM 696,40 (356,00 EUROS)/tonne of packaging waste (Hanisch 2000). "Who is to say whether it is worth it?" queries Fishbein. However, from the year 2005 onward, municipal waste in Germany will have to be incinerated, and only landfilling of the residues will be permitted according to a new federal ordinance. Given the public resistance to new incineration plants and the conspicuousness of plastics waste, the decision was made to implement a recycling scheme for packaging (Patel *et al.* 2000).

It has been criticised that promoting recovery of packaging waste from consumers may successfully remove materials from the waste stream, but not without environmental consequences (Neumayer 2000). According to Neumayer, the European Union's Packaging Waste Directive prioritises innovative development of recycling technologies at the cost of neglected opportunities for avoiding waste generation in the first instance. He argues that avoidance saves the full material and energy content of packages, but recycling only favours partial recovery of the resources and energy embodied in waste. Due to high costs for separate collection, sorting and processing, recycling costs are often very great. Transportation is also a crucial issue. Based on case studies presented by Kirkpatrick (1992), it was concluded that due to poor infrastructure currently existing, the average distance travelled for the purposes of recycling operations is 250 km facilitated

by 9 tonne diesel-powered trucks with an average utility of 50%. Eight years on, it still appears to be true. Figure 11 illustrates the journey of recyclables, recovered from separate waste collection receptacles in Oulu to recycling facilities in 1999.

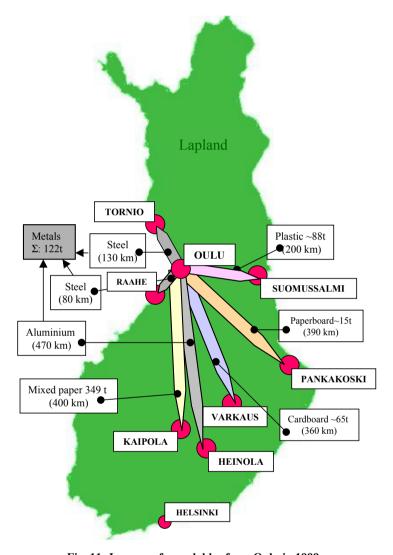


Fig. 11. Journey of recyclables from Oulu in 1999.

Oulu is the sixth largest city in Finland, and some recyclables, such as liquid board containers, travel 360km to Varkaus, since that is the only recycling facility for these types of packaging. As referred to earlier, mixed paper travels 400 km. After the new Waste Act in Oulu (Oulun kaupunki 2000), the situation only worsened, as illustrated with Fig. 12, since greater amounts of paper and board now travel, occasionally, even longer distances. Paper is also collected from the northernmost points of Finland. One

cannot help wondering: Is it really environmentally friendly to transport paper, or board from the outer limits of Lapland to Kaipola, or Pori, with road distances ranging up to 1 000 km?

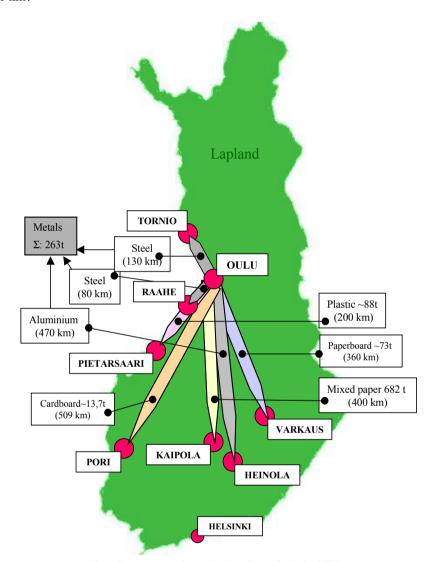


Fig. 12. Journey of recyclables from Oulu in 2001.

On the subject of the Proximity Principle cited earlier, according to the Article 5 of the Waste Directive (European Council 1991a): "Member States shall establish an integrated and adequate network of disposal installations." Hence, local organisations will also take appropriate steps to ensure the disposal of their waste according to the Proximity Principle: as nearby as possible to the place where it was produced. However, the European Court of Justice modified this statement later in the Dusseldorp case (Jans

1999) by saying that "the Proximity and Self-sufficiency Principle cannot be applied to waste for recovery."

A study was aimed at analysing separation strategies fulfilling the recovery rate targets in the Helsinki area, where in 1995, the total recovery rate was 27wt.%. The strategies studied were first based only on source separation, resulting in the highest recovery rate of 66wt.%. At the same time, the costs of Municipal Solid Waste Management (MSWM) increased by 41%, when compared to the year 1995. Subsequently, a recovery rate of 74wt.% was attained by combining source separation with central sorting of mixed waste. As a result, the costs of MSWM increased by 30% compared to the present situation. (Tanskanen 2000.) However, in both of these strategies, the emissions caused by MSWM were generally reduced.

Another study on national separation strategy for MSW in Finland concluded that the maximal national recovery rate of MSW, which can be reached with source separation, is in the area of 55%wt, with the present separation activity of waste producers. The final conclusion of this study was that recovery rates in the region of 35-50%wt are more realistic in practice, for the reason that it seems improbable that an all-inclusive, on-site collection system would be applied for all recoverable materials in such a sparsely populated country as Finland. The study concluded that national recovery rate targets should also be divided into regional sub-targets because the total waste amount produced, transfer distances, and sizes of properties vary greatly between Finnish municipalities. (Tanskanen & Melanen 2000.)

A report has also been prepared by the Institute for Prospective Technology Studies (IPTS) for the Committee for Environment, Public Health and Consumer Protection of the European Parliament, on the impediments and prospects of the recycling industry in the European Union. The conclusions of this study were as follows (Bontoux *et al.* 1996):

"Recycling is not always necessarily the preferable waste management solution since it is limited by the Second Law of Thermodynamics and obeys the law of diminishing returns. Other options such as prevention, re-use, and recovery of energy can offer ecological or economic advantages over recycling according to the application area. In this light, the growth of the recycling industry is not a necessarily desirable policy target." ²

Coggins (2001) views recycling as an 'end-of-pipe option;' Dijkema labels the total waste management system an 'end-of-pipe system' (Dijkema *et al.* 1999), and both call for 'resource management' rather than waste management. Bontoux *et al.* (1996) opt for the establishment of operational definitions and statistics as a crucial point to ensure a proper functioning of the European single market in the area of recycling, and to provide the basis for a systematic harmonisation of the national legislation affecting recycling.

In Finland, an extensive research project on the efficacy of waste policy instruments (WAPO), was carried out from 1998 to 2000 as part of the Finnish Environmental Cluster Research Programme. According to WAPO, the infrastructure of waste management and the recovery of wastes have greatly improved in Finland in the 1990s. However, the waste policy has not been able to promote waste prevention, the primary objective defined in the Finnish Waste Act and the EU's waste policy (Melanen *et al.* 2002). Finland calls for

^{2.} Emphasis in the last sentence of the above citation has been placed by the author of this thesis.

the re-evaluation of the Packaging Directive, and for promoting packaging waste prevention rather than recycling. As a case in point, in Finland the per capita packaging waste is half of that of the EU's, due to widespread re-use of primary as well as transport packaging (Heino 2000).

In summary, the concept of recycling to conserve resources is based on the assumption that recycling requires fewer raw materials and less energy, and generates fewer emissions into the environment, than manufacturing new material. However, one can conclude that recycling is not environmentally sound when it requires transportation over unreasonably long distances, using non-renewable fossil fuels. For recycling to be environmentally beneficial, the effects of the collection, transportation and reprocessing operations must be less harmful than those resulting from the extraction and processing of the raw materials that the recycled product replaces. Recycling alone, without avoidance at source, will not result in overall reduction of the amount of waste produced. Recycling addresses only the disposal of a product when it becomes waste, rather than its generation, thus it only recovers the energy and material included in the product, whereas prevention addresses the energy and material use of the whole production chain. It is important to stress that, while recycling is a mechanism for achieving environmental goals, it should not become a goal in and of itself. We might move forward from the efforts of practising 'recycling-for-recycling's-sake' towards waste prevention. To that end, it is important to ensure necessary education, to provide a range of environmentally beneficial choices and genuine incentives to help make the right choices.

3.6 Quo vadis waste management?

The human population and its economy are dependent upon constant flows of air, water, food supply, raw materials, and fossil fuels from the Earth. Wastes are continually generated and are either emitted into the air or dumped back onto/into the Earth. The global population has been growing at a roughly exponential rate since the beginning of the Industrial Revolution. Prior to that era, environmental constraint on growth was local, not regional or global, so intra- and inter-species competition involving humans did not challenge the perception of the desirability of growth. As a result, most human institutions and intellectual disciplines implicitly assume that continuing rapid growth is both feasible and desirable. They embody the assumptions and attitudes appropriate for an exponential growth phase, not the carrying capacity phase. Consequently, most economic approaches favour an aversion to implied limits to growth, especially reduced growth in capital stock. In the field of law, the obvious example of the 'now is better' approach is the failure of the legal system to recognise any rights of parties not present in a dispute, thus depriving the rights of future generations. This attitude does not encourage accountability by human societies either. (Meadows *et al.* 1992.)

Meadows et al. are the authors of the much-disputed The Limits to Growth, which was a report on their two-year investigation on the long-term causes and consequences of growth in population, industrial capital, food production, resource consumption, and pollution. The publication of the book created a furore. Parliaments and scientific societies debated it. A major oil company sponsored a series of advertisements criticising

it; another set up an annual prize for the best studies expanding upon it. It was interpreted by many as a prediction of doom, but it was *not* a prediction at all. It was not about a preordained future, but about a choice. It contained a warning, but also a message of promise (Meadows *et al.* 1972). The conclusions of *The Limits of Growth* have been reconsidered, by the authors of same, twenty years later. The book carries a warning that human usage of many essential resources and generation of many kinds of pollutants has already surpassed rates that are physically sustainable. To remedy this, a rapid and drastic increase in the efficiency with which materials and energy are used is needed. (Meadows *et al.* 1992.)

It is concluded that the transition to a sustainable society requires a careful balance between long-term and short-term goals and an emphasis on sufficiency, equity, and quality of life rather than on quantity of output. It requires more than productivity and more than technology; it also requires maturity, compassion and wisdom (Meadows *et al.* 1992). It is time that society began to allocate its resources to the technologies of pollution control, land preservation, human health and resource-use efficiency. As set forth in the programme for research, technological development and demonstration on energy, environment and sustainable development (European Council 1999a):

"Environmental problems, energy systems, networks and services and the associated environmental impacts, as well as sustainable development issues must be approached in the global context. [...] Improving our quality of life and de-coupling economic growth from environmental degradation will contribute to European competitiveness and employment. Enormous potential will exist for global exploitation from several areas of the programme, strengthening economic competitiveness and creating new jobs, such as in the water industry, renewable energy technologies, rational use of energy and re-use of resources, as well as technologies to improve energy efficiency and the water and/or energy industries."

Waste management is part of the 'global context' as mentioned above. One of the priorities of this programme is an integrated approach to better use and conservation of resources and reduced pollution and waste. The stress is on the integrated approach: reduction of waste, energy efficiency, pollution prevention, and even water usage will be equally considered in concert, not as distinct from one and other.

4 Defining Waste

"To waste or waste not – it's all in the definition." – B. Quinn

Every term used in a scientific theory or in a given branch of science ought to be precisely defined. Definition may seem the most obvious, and perhaps the only adequate method of characterising a scientific concept. Let us consider this procedure: Definitions are offered for one or the other of two different purposes, namely (Hempel 1966):

- 1. To state or describe the accepted meaning, or meanings, of a term already in use;
- To assign, by stipulation as special meaning to a given term, which may be a newly coined verbal or symbolic expression or an 'old' term that is to be used in a specific technical sense.

Definitions serving the first purpose will be labelled as descriptive; those serving the second purpose will be termed stipulative.

The intention of definitions is that a term defined by an analytic or a stipulative definition can always be eliminated from a sentence by substituting its *definiens*. Descriptive definitions are of the form (Hempel 1966): *Definiendum* has the same meaning as *definiens*. While stipulative definitions can be given the form: *Definiendum* is to have the same meaning as *definiens*.

Definition is always important in the field of law, but it is particularly important in a system of regulatory control, as it is necessary to define what can and cannot be controlled. Ideally, the legal definition should be sufficiently extensive to encompass all the activities that need to be controlled, but not so broad that it results in over-regulation. (Cheyne & Purdue 1995.)

Effective definitions of core concepts have several important characteristics (Love 2002):

- To be an epistemologically well-bounded theoretical construct;
- Have the same role and purpose all around the intended areas of research and theory making;
- Provide both necessary and sufficient conditions for the definition to apply;
- Not be constructed solely on other concepts to form a complete set of theoretical building blocks with which to construct and develop a larger body of theory/knowledge.

Community waste policy was embraced from the outset, dual objectives of resource conservation and disposal policy. In hindsight, this means that many of the original Waste Directives could be readily criticised for their vagueness (Tromans 2001). Problems included the lack of clear definitions on key terms. Opinions diverge sharply on fundamental questions such as the proper definition of waste, and the related issue of the appropriate scope of regulation recyclable secondary materials (Smith 1993). This chapter is, therefore, concerned with the descriptive definition of the term 'waste'.

4.1 Waste definitions

The concept of waste seems 'obvious.' In an effort to demonstrate just how much it is *not* obvious. Table 15 summarises some current definitions of waste:

Table 15. Definitions of waste.

EU	Waste shall mean any substance or object in the categories set out in Annex I which the holder discards or is required to discard (European Council 1991a).
OECD	Wastes are materials other than radioactive materials intended for disposal, for reasons specified in Table 1 (OECD 1994).
UNEP	Wastes are substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law (UNEP 1989).

One method of defining waste is by a listing of activities or substances which come within the range of definition. An alternative technique would be to define by reference to the purpose of the regulation. Most regulatory systems adopt a mixture of the two techniques (Cheyne & Purdue 1995). The Commission, acting in accordance with the procedure laid down in Article 18, drew up a list of wastes belonging to the categories listed in Annex I: the European Waste Catalogue (EWC). Annex I is identical to 'Table 1' of the OECD, and shown here in Table 16. This catalogue will be periodically reviewed and, if necessary, revised by the same procedure. It contains a total of 700 items, several of them being of the type "waste not specified elsewhere." Cheyne and Purdue (1995) consider that this catch-all category is necessary because there is no absolute objective or external clue as to whether a substance or object should be considered as requiring waste management. EWC also states that "The inclusion of a material in the EWC does not mean that the material is a waste in all circumstances." Article 1 requires the substance to be both listed in Annex 1 and be discarded (Cheyne & Purdue 1995). Thus, it does not resolve any uncertainties that may arise from the definition of waste from the framework Waste Directive, nor does the definition offered by the OECD.

What appears to be common in the definitions listed in Table 15 is that waste is something that its holder has disposed of, or discarded.

Table 16. Annex I - Categories of Waste (European Council 1991a).

- Q 1 Production or consumption residues not otherwise specified below.
- Q 2 Off-specification products.
- O 3 Products whose date for appropriate use has expired.
- Q 4 Materials spilled, lost or having undergone other mishap including any materials, equipment, *etc.* contaminated as a result of the mishap.
- Q 5 Materials contaminated or soiled as a result of planned actions, e.g. residues from cleaning operations, packing materials, containers, etc.
- Q 6 Unusable parts, e.g. reject batteries, exhausted catalyst, etc.
- Q 7 Substances, which no longer perform satisfactorily, e.g., contaminated acids, contaminated solvents, exhausted tempering salts, etc.
- Q 8 Residue of industrial processes, e.g. slags, still bottom, etc.
- Q 9 Residues from pollution abatement processes, e.g., scrubber sludges, baghouse dusts, spent filters, etc.
- Q 10 Machining/finishing residues, e.g. lathe turnings, mill scales, etc.
- Q 11 Residue from raw material extraction and processing, e.g. mining residues, oil filed slops, etc.
- Q 12 Adulterated materials, e.g. oils contaminated with PCBs, etc.
- Q 13 Any materials, substances or products whose use has been banned by law in the country of exportation.
- Q 14 Products for which there is no further use, e.g. agriculture, household, office, commercial and shop discards, etc.
- Q 15 Materials, substances or products resulting from remedial actions with respect to contaminated land.
- Q 16 Any materials, substances or products which the generator or exporter declares to be wastes and which are not contained in the above categories.

Initially, the 1975 version of the Waste Directive defined waste as "any substance or object which the holder disposes of, or is required to dispose if pursuant to the provisions of national law in force." This immediately raises the issue of what is the difference between 'disposal' and 'discard,' and why it was thought necessary to substitute discard for disposal in the EU definition. Principally, both 'dispose' and 'discard' mean 'getting rid of', but most dictionaries suggest that 'disposal' is to put in a suitable place (it can include sales and transfer of ownership), while 'discard' has the connotation of rejection of something, since that something is seen as useless or undesirable. Cheyne and Purdue argue that 'discard' has a narrowed meaning, and it can be viewed as a careless act in the sense that the discarder does not care what becomes of the object. On the other hand, 'disposal' suggests a deliberate and thoughtful act. They assumed that the purpose of the use of the term 'discard' instead of 'dispose' was to broaden the reach of the Directive and include the widest possible acts of doing away with things – with or without interest in the final destination of the discarded things. (Cheyne & Purdue 1995.) A significant problem is how to stretch the limits of the meaning of 'discard' to include actions where the things are not unwanted, for example, re-use. Fluck (1994) argued that there is a need to separate the meaning of the term 'discard' from the lists of recovery (see Table 4) and disposal (see Table 6) operations, and develop a neutral 'discarding concept.' To this end, Fluck defined discard as:

"[...] an action whose purpose is to desist from using a substance or object for its original purpose, to liberate it from that intended purpose, or to re-dedicate it, without immediately allocating it to a new intended purpose, certain recovery activities being necessary to make it fit once again for its former purpose (recovery), or the substance or object being definitely withdrawn from any further use (disposal)."

Cheyne and Purdue (1995) agree that 'discard' defined from Fluck's approach does not mean 'getting rid of' a thing, but it is an action that changes the original purpose of the thing. Thus the result is that the thing is either "withdrawn from any further use" (disposed of), or "put either to the same or some other purpose" (recovered).

While the reasoning is certainly intriguing, one cannot help wondering – as in the case of defining re-use – about those things that have never had any purpose. Furthermore, if one analyses the recovery operations listed in Table 4, operations R1-R8, all recycling and regeneration operations, appear to be reprocessing, that is repairing the state or structure of the things so that they can perform again with respect to their *original* purpose.

In the case of disposal operations (see Table 6), it is not the purpose that is manipulated, rather it is the structure, or state. Except storage operations, all disposal operations appear to render the thing permanently non-retrievable (discharging into air, water bodies, or incineration). Due to these factors, the thing will no longer be recognisable, and it can be further argued that they are no longer artefacts, that is, they do not have any purpose.

In summary, the listed recovery and disposal operations – with a few exceptions – appear to be manipulating the structure and state rather than the purpose. Nevertheless, the author cannot help wondering why it is necessary to define waste with respect to what is going to be done with it. Would it not be more viable to define waste with respect as to how it became waste?

An interesting analysis would be to try to replace the term 'waste,' in one of its many definitions with 'a thing that its holder is to discard.'

Waste management, as it is understood today (the collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites) is truly concerned with things that were (and are) to be disposed of. However, waste minimisation is by far not only trying to minimise the amount of things to be disposed of, since, as outlined in Chapter 2, waste minimisation includes three options:

- 1. Preventing and/or reducing the generation of waste at source.
- 2. Improving the quality of the waste generated, such as reducing the hazard.
- 3. Encouraging re-use, recycling and recovery.

'Minimising the amount of things that the holder intends to dispose' covers only the third option of waste minimisation. It does not cover the first, most important option, since this description of waste presupposes that the wasted thing is already there, and the holder intends to dispose of it; whereas the principal meaning of waste minimisation is to avoid the waste ever being created.

If these definitions do not precisely describe waste, how can one distinguish a waste from a non-waste? If one sees a thing, how would one *decide* if it were a waste or not? By asking: has someone disposed of this thing? (How can one ever tell for certain?) Even if

the answer was 'yes,' would that mean that the thing in question is then a waste? What if the question is posed: 'Would I have had disposed of this same thing, if I would have owned it?' What occurs if the answer is 'no?' Is the thing then a waste, or not? The answer is that one can make an individual decision if the waste is a personal one, but it should not mean that the particular thing is a 'universal waste'. Waste is a value concept, culturally construed and subjective to the individual, be it the observer or the disposer. Consequently, if we are to associate waste with humans, we shall not ever be able to define waste objectively.

Therefore, might there be an other method of describing waste? Classifying wastes into groups, as the EU Directive's Annex I intends, is somewhat more useful. It lists all the known wastes that are present, so if one particular industrial residue is included in Annex I, it can be safely assumed that it is a waste. However, the classification itself states that "the inclusion of a material in the EWC does not mean that the material is a waste in all circumstances." The European Commission also recognises that, to date, there is no satisfactory definition of when a product becomes waste, nor of when a waste becomes a product again (Bontoux & Leone 1997).

The reason is that legislation deals with existing waste. It appears to accept the fact that people, industries, institutions discard, discharge, or emit things useless to them, and is concerned with the 'what to do with it?' dilemma. This is understandable and necessary: the main goals of the existing European legislation on waste are the protection of public health and the environment. It is for the practical side of waste management, and it can be argued that the state of the art of waste management is a practical field.

However, it is essential to aim at the scientification of waste management and, additionally propose a theory for it. If a proposed theory is to have a comprehensible meaning, then the theoretical concepts that are crucial for its formulation have to be clearly and objectively defined in terms of concepts that are already available and understood. The definition of waste is crucial to this evolving theory; indeed, it is the core of the theory. Suppose we were to treat definitions as hypotheses and follow Hempel's (1966) explanation of the basic steps in testing a hypothesis as follows: Test implication of a hypothesis means that, if the hypothesis (H) were true, then certain observable events (test implications – I) should occur under specified circumstances, schematised as follows:

If H is true, then so is I
But if (as evidence shows) I is not true
H is not true

Any argument of this form, called *modus tollens* in the field of logic, is deductively valid; that is, if its premises are true, then its conclusion is unfailingly true as well. This way of testing hypotheses can be used in testing definitions. We have a definition (D) of waste. If every waste thing (W) can be said to be exactly as described in the definition, then we can accept the definition as valid. However, if there are waste things that are not covered by the definition, then the definition cannot be considered a credible scientific definition.

It can be argued that definitions of the type 'things that the holder disposes of for specified reasons' do not cover every type of waste. It is actually **not** the explicit purpose of definitions used in legislation to conceptually describe waste. It is rather a marker,

arguably a 'ticket' to the waste treatment or disposal facility. This label does not necessarily mean that the thing is 'ultimately a waste,' it rather means that the thing will be treated like waste. As well, definitions of the type 'things belonging to one in the prespecified (700) categories' cannot be considered as scientific definitions, particularly if the categories contain classes such as "not otherwise specified" (Q1 of Table 16). One could ask: Is it really impossible to come up with a comprehensive definition that describes every piece of waste beyond doubt?

4.2 The notion of waste

The notion of waste is relative in two main respects. First, something becomes waste when it loses its primary function for the user, hence someone's waste output is often someone else's raw material input. Secondly, the notion of waste is also relative to the technological state of the art and to the location of its generation. Waste is therefore a very dynamic concept.

The European Chemical Industry Council (CEFIC) argues that it is not the nature of the material which determines whether it is waste, but only the actions or intentions of the holder. Therefore, only those materials for which the holder has no further use and which he discards, or intends to discard, are waste (CEFIC 1995). Their discussion paper on the definition of waste argues as has been paraphrased in the ensuing paragraph.

The chemical industry is mainly concerned with productive processes. A production process gives rise to products, by-products, recoverable materials and waste. The aim of the production process is to manufacture one or several products. In addition to these primarily desired products, chemical process inherently often result in other substances, which can be beneficially used in other production processes and normally are called byproducts. Both products and by-products are planned or intended results of the production process in the sense that the process unit is designed and operated to produce these substances according to clearly defined specifications. The products and by-products are either produced internally as raw material in the next step of a production chain or in another production process, or are sold on the market, or transferred to another producer to be used directly in this production process as raw materials. Some materials used in a production process can become contaminated and must be regenerated so that they can be re-used in the process. Since the holder has no intention of discarding these materials, as a result they are not wastes. (CEFIC 1995.) CEFIC also calls for developing criteria to distinguish by-products from waste. However, one cannot help feeling dubious about defining something, i.e.: giving an adequate characterisation to a scientific concept, based on an intention (see Table 8, definition of waste).

The Community Directive on Waste (European Council 1991a) introduces a distinction and provides for different permits between disposal operations and recovery operations. This legal situation has created a number of disputes that had to be, or are to be resolved at the European Court of Justice (ECJ) level. Among others, it was referred to the ECJ for ruling whether waste may be classified as *re-usable residue* and thus fall outside the scope of the legislation on waste. The Court held that (Purdue 1998):

"[...] a substance of which its holder disposes may constitute waste within the meaning of Directives 75/442 and 78/319 even when it is capable of economic re-utilisation."

At the same time, the Directive (European Council 1991a) recognises the need to ensure a "common terminology and definition of waste" in order to improve the efficiency of waste management. It also emphasises the desirability of encouraging the "recycling of waste and re-use of waste as raw materials" (Purdue 1998). The Court based its decision on the fact that both Directives stressed the importance of encouraging recovery of waste and that disposal of waste within the meaning of the Directives included the transformations necessary for its recovery, re-use and recycling. Several submissions were made in this case to the Court (Ibid.):

- The Italian Government argues that the waste definition places importance on a subjective element, namely the decision of the holder to discard the substance or object.
- The Danish Government contends that the notion of waste covers all residual products. Residual products are, by definition, not the goal sought by a production process. They do not have a constant economic value, their use depends on what markets are available for them.
- The French Government also seems to take a broader view of the notion of waste, observing that waste, including a residue, continues to be waste until it has been recovered
- In The Netherlands, a substance must not necessarily be classified as waste if the substance is transported directly from the producer to the person who will make further use of it, it must be 100% utilised in a production process, and must not be subject to any process comparable to a current means of waste disposal or recovery.
- The United Kingdom argues that a substance is to be regarded as waste if it leaves the normal commercial cycle, or the normal chain of utility and is consigned to a specialised recovery operation.

The Commission rejects the use of concepts such as 'continuity of economic or utility cycle' in favour of a case-by-case approach on a broad interpretation of the legislation. The judgement of the Court affirms that the definition was not to be understood to exclude substances just because they were capable of economic re-utilisation. What the judgement avoids is a definition of what is meant by the term 'discard' and whether the action of *recovering* an article by any of the recovery operations means that the article is being *discarded*. (Purdue 1998.)

The problem arises because there is no explicit link between the term 'waste' and the 'disposal' and 'recovery operations' (Cheyne & Purdue 1995). Advocate General Jacobs argued in the Euro Tombesi case (Case C-304/94), as van Calster (1997) referred to 'Euro Tombesi bypass:'

"[...] the term 'discard' employed in the definition of waste in Article I(a) has a special meaning encompassing both the disposal of waste and its consignment to a recovery operation. The scope of the term 'waste' therefore depends on what is meant by 'disposal operations' (Annex IIA) and 'recovery operations' (Annex IIB)."

However, Jacobs' bypass obviously extends the meaning of 'discard' beyond its normal meaning. Furthermore, some of the categories (see Table 4, R8 & R10) involve no stage of prior treatment before the material is put to a use. Thus Purdue (1998) points out that the distinction between the recovery of waste and the further use of residues left over from a particular process is somewhat fragile. Jacobs accepts that the simple transfer of goods for use in their existing form cannot itself be a recovery operation by arguing (Purdue 1998):

"It may nevertheless be inferred from the term 'recovery operation' itself and from the list of Annex IIB set out above that what is entailed by 'recovery' is a process by which goods are restored to their previous state or transformed into a usable state or by which certain usable components are extracted or produced."

What Jacobs has not clarified is, whether he agrees that it would be inappropriate to conclude that a substance has been discarded solely on the grounds that it has been consigned to a recovery operation. Purdue (1998) suggests that Annex IIB could be interpreted restrictively, and "to exclude from the term recovery operation re-uses of materials of which there is no transformation process."

4.3 Effects of the current definition of waste

The waste regulations within the EU are generally considered to have had, so far, a positive effect on the environment. However, care should be taken that it remains so, and that the increasing complexity of the legislation does not decrease the level of environmental protection. As mentioned in the preceding section, the present definitions of waste have created legal disputes in Europe as well as overseas. It is because a substance, when defined as waste, is often restricted in its transport, sale and re-use. In Europe, industry has voiced serious concerns that definitions may become a barrier to efficient and sustainable European waste management. Defining a material as waste, or secondary raw material, bears many consequences on what is permissive or not, what administrative procedures apply to its transport, export or processing, and what costs will be incurred. To this extent, the Chairman of the Committee for Environment, Health and Consumer Protection of the European Parliament requested the Institute for Prospective Technologies Studies to perform a study to understand the consequences of the legal definitions of waste on waste management in Europe, and in particular, the recycling, treatment and disposal of waste (Bontoux *et al.* 1996).

The EU's waste policy requirement to "guarantee a high level of protection for the environment and public health" (European Council 1990) is largely achieved. However, the administrative and control requirements for handling 'waste' entail wide-ranging consequences, both directly and indirectly. In the beginning of the 1990's, Rushbrook made a prediction that, by the end of 1990's, all waste regulatory agencies across Europe will have a single waste classification system (Rushbrook 1992). This prediction realised partial success, as the EU did agree on a Waste Catalogue, but individual, national laws still have different definitions for wastes (Rushbrook 2000). It is due to the lack of precision of the definition of 'waste' in the Directive, that each Member State makes a

different interpretation of the definition of waste (see Table 17) with regard to specific materials, which results in trade barriers. The impact on the recycling industry is clear. Under the definition of waste, recoverable material is seen more as a potential pollutant than as a potential raw material. As such, their movement between EU and non-OECD States falls under the restrictive conditions of the Basel Convention (European Council 1993a) if they are "hazardous," or deemed to be so by the country of export, import or transit. (Bontoux & Leone 1997.)

Table 17. Comparison between the definition of waste in Directive 91/156/EEC and national definitions (Bontoux & Leone 1997).

Countries	Legislation	Definition of waste
EU	75/442/EEC	Any substance or object, which the holder disposes or is
		required to dispose of pursuant to the provisions of national law in force.
	91/156/EEC	Any substance or object in the categories set out in Annex I which the holder <u>discards</u> or intends or is required to discard.
Austria	Austrian Waste Management Act 1990 last revised by GBI. Nr. 434/ 1996	Objects which an owner or holder wishes to dispose or disposed of, or where their collection and treatment as waste is required by the public interest. EWC is not mentioned.
Belgium	Region Wallone: Decree 27 June 1996; Flamish Region: Decree 2 July 1982, amended 20 April 1994	As 91/156/EEC, but without mentioning EWC.
Denmark	Statutory Order n. 299 of 30 April 1997	As 91/156/EEC with EWC.
Finland	Waste Act 1072/1993	As 91/156/EEC with EWC.
France	French Act 75-633 1975 revised 13 July 1992	Material originating from a production or transformation process, or use, which the holder discard or intends to discard. Distinction between "waste" and "ultimate waste" is made.
Germany	Waste Management Act (RWMA) 1994	As 91/156/EEC with EWC.
Greece	n.a.	As 75/442/EEC not updated to 91/156.
Ireland	Environmental Protection Act July 1996	As 91/156/EEC with EWC.
Italy	Decree 22/97	As 91/156/EEC with EWC.
Luxembourg	n.a.	Any substance or object which the holder abandons or is required to discard, Also considers waste any product or substance that sent for recovery until it enters the commercial chain again.
Portugal	n.a.	As 75/442/EEC not updated to 91/156.
Spain	n.a.	As 75/442/EEC not updated to 91/156.
The Netherlands	Wet Milieubeheer 1993	As 91/156/EEC, but without mentioning EWC.
United Kingdom	Environmental Protection Regulations (1991)	As 91/156/EEC, but without mentioning EWC.

In the metals industry, complexity of non-ferrous metals recycling increases in all the cases where the materials are toxic, and where adverse environmental effects can be

associated with the recycling operations. In this context, the Basel Convention can be perceived as a barrier (Bontoux *et al.* 1996). According to the International Council on Metals and the Environment (ICME), the Basel Convention does not differentiate between materials for recycling and materials for disposal, therefore, it strongly affects the economies of industrialising nations that have recently been increasing their nonferrous scrap imports from industrial countries (Cambell 1996). The freedom of international movement for secondary non-ferrous metals, under environmentally sound conditions, is one of the key recommendations made by the European Non-ferrous Metals Trade, recovery and recycling industry to the European Commission (Eurometaux 1992).

In this light, the most telling indicator of the success of the Basel Convention is not so much its ability to reduce trade flows from OECD countries, but the effect that it has on the capacity of developing countries to manage their own wastes effectively. It can be argued that some of the aspects of the Convention actually discourage the development of such capacity, given that reduced exports of hazardous waste from OECD states will reduce incentives for them to transfer waste management technology to non-OECD countries (Johnstone 1998).

The OECD, in its decision/recommendation on the reduction of trans-boundary movements of wastes, recognises the desirability of appropriately controlled international trade in waste materials destined for environmentally sound operations, leading to source recovery, recycling, reclamation, direct re-use or alternative uses. It is convinced that there is a need to reduce trans-frontier movements of all wastes to a minimum. In particular, to reduce the trans-frontier movement of waste not subject to recovery operations. However, it is recognised that efficient and environmentally sound management of waste may justify some trans-frontier movements in order to make use of adequate recovery or disposal facilities in other countries. Thus, the committee calls for the clarification of the definitions of waste and a characterisation of those wastes, which may require different levels of control. (OECD 1991.)

Some of these substances may represent valuable raw materials, which the holder may want to use or sell. In such circumstances, the role of the term 'discard' may be paramount in deciding whether the substance or object constitutes a waste, the requirement of discarding will always be important since it forms an essential part of the definition under Article I (Cheyne & Purdue 1995).

4.4 Waste versus non-waste: national and international approaches

The concept of non-waste was introduced by French regulators in response to restrictions imposed by the present, legal waste definitions and regulations, to identify "ultimate wastes" as opposed to wastes that could be utilised (Bontoux & Leone 1997). There appears to be an emerging recognition within some Member States of the EU that waste collected for recycling purposes should be defined as a secondary raw material. The Community strategy for waste management (European Council 1997) also recognises the particular need to distinguish more clearly between waste and non-waste goods. The question is: where should the line be drawn between product and waste on one side, and between waste and raw material (or product) on the other? Bontoux and Leone (1997)

argue that if a material is wholly interchangeable with another product and does not fall under additional regulation, it is unnecessary for it to be classified as waste.

Some European Member States have developed different approaches and sets of criteria to distinguish waste from non-waste (Bontoux & Leone 1997). They are summarised in Table 18.

Table 18. Criteria distinguishing waste from non-waste in various European countries (Bontoux & Leone 1997).

Country	Criteria distinguishing waste from non-waste		
Austria	Public interest shall not require a systematic listing and treatment as waste as long as the		
	substance meets the following conditions:		
	- it is new, or used for its intended purpose and meets generally accepted user standards;		
	- it is used in an admissible way; or		
	- it is recycled in the immediate vicinity of a household or a place of business, after		
	having been put to its intended purpose.		
Belgium	A substance integrated into an industrial production process constitutes waste only if it is		
	used in a way which is not in conformity with the nature or function assigned to it under a		
	natural process, or assigned to it intentionally under a production or other process.		
France	A non-waste should:		
	- have a use value;		
	 have recognised characteristics and meet specifications defined by the user; 		
	- have identifiable, stable users in the medium term;		
	- be traceable from production through to is ultimate state;		
	- benefit from a non-discard guarantee throughout the recovery cycle;		
	- be consistent with a high level of environmental protection;		
	- have clear contractual relations between it producer and user.		
The Netherlands	A non-waste must:		
	- be used 100% in a production process;		
	- not be subject to any process comparable to a current means of waste disposal or		
	recovery; or		
	- be transported directly from the producer to the person who will make use of it.		
United Kingdom	Production residues, secondary raw materials, and by-products used in industrial		
	processes do not constitute waste if they are not subjected to an operation associated with		
	the recovery of waste. A recyclable material is not "waste", if it is:		
	- material which is within the "commercial cycle or chain of utility"		
	- materials which can be put into immediate use without going through a specialised		
	waste recovery operation; or		
	- waste which has been processed to such state that it can be used as a raw material.		

The OECD has also recognised the need to develop a system of indicators to provide practical guidance in the distinction between waste and non-waste. As a result, a list of questions to be organised in a flow chart has been proposed in draft form under OECD guidance documents (OECD 1998). These are summarised in Table 19. It should be noted that no particular weighting can be assigned to any of the considerations listed in the following table below. In order to comprehensively evaluate the statutes of a material, all of the considerations in Table 19 may be applied on a case-by-case basis. Although many Member States supported the concept of a flow chart as a means of providing guidance, others did not support this concept. Moreover, the effort to incorporate all the possible

scenarios into one flow chart merely illustrated the inherent circularity of the waste definition. (OECD 1998.)

Table 19. The OECD system for the distinction between waste and non-waste (OECD 1998).

General considerations	Is the material produced intentionally?		
	Is the material made in response to market demand?		
	Is the overall economic value of the material negative?		
	Is the material no longer part of the normal commercial cycle or chain or utility?		
Characteristics and	Is the production of the material subject to quality control?		
specification	Does the material meet well-developed nationally and internationally recognised specification/standards?		
Environmental impact	Do these standards include environmental considerations, in addition to technical or economic considerations?		
	Is the use of the material as environmentally sound as that of a primary product?		
	Does the use of the material in a production process cause any increased risks to		
	human health or the environment greater than the use of the corresponding raw material?		
Use and destination	Is further processing required before the material can be directly used in a		
of the material	manufacturing/commercial application?		
	Is this processing limited to minor repair?		
	Is the material still suitable for its originally intended purpose?		
	Can the material be used for another purpose as a substitute material?		
	Will the material actually be used in a production process?		
	Does the material have an identified use?		
	Can the material be used in its present form or in the same way as a raw material		
	without being subjected to a recovery operation?		
	Can the material be used after it has been subjected to a recovery operation?		

In brief, the situation concerning the European waste definition is well-described by Bontoux and Leone (1997): "The waste issue is now creating a turmoil in Europe, within many industrial sectors, in particular those involved in recovery and recycling." A large part of this turmoil comes from the fact that the current definition of waste from the European framework Directive is very broad and includes materials that were long considered by some actors as not being wastes. The complexity of the matter is striking, as well as the number of misunderstandings occurring in the communications between the many actors involved. The bottom line is the different interpretations of the definition of waste, and the uneven application of European legislation, and that these differences interfere with long-established practices in waste management and recycling. The consequences are felt at environmental, economic and even world trade levels. As a result, there is a strong need to take a fresh look a the issue of waste management, always keeping the ultimate objectives of European policy in mind, *i.e.* sustainable development, conservation of natural resources, environment and public health protection, employment and economic growth.

It is, therefore, essential to analyse the nature of waste, and try to arrive at a better description of waste. The author has noted in the Introduction of this work that there is a need for a 'clear and objective' definition of waste. It is disputable if it is possible at all, since if we consider waste a human-related value concept that is culturally construed, it cannot have an objective definition. The author feels that the approach to the waste

question should be viewed from an alternative perspective: Not from 'why would or would not' a human dispose or discard something, but 'why did the thing become waste' in the first instance.

4.5 What is waste?

Waste is bound together with life. Organisms alter their environment by taking in free energy and excreting high-entropy waste in order to maintain low internal entropy (Schrodinger 1944). In attempting to find a physical basis for detecting presence of life on a planet, Lovelock (1965) recognised that most organisms shift their physical environment away from equilibrium. In particular, organisms use the atmosphere of a planet to supply resources and as a repository of waste products. In contrast, the atmosphere of a planet without life should show less disequilibrium. For example, the atmospheres of Mars and Venus are dominated by carbon dioxide and are only in a mild state of equilibrium (Hitchcock & Lovelock 1967). In contrast, the atmosphere of the Earth is in an extreme state of disequilibrium in which highly reactive gases such as methane and oxygen, exist together at levels that are different by many orders of magnitude from photochemical steady states (Lovelock 1972). This concept actually became the founding impetus of the Gaia hypothesis (Lenton 1998).

It is interesting to note how waste is defined in other relationships, and not as related to material things. Stanbury and Thomson (1995) conducted a research study on defining 'government waste.' In their survey they realised that few authors bothered to define this term. They offer plenty of examples, but seem to assume that the concept is wellunderstood. As an explanation on what government waste is, according to former Vice President of USA, Al Gore (1993), "the average American believes we waste 48 cents of every tax dollar." For instance, in relation to government waste, McKinney (1986) defined waste as "the unnecessary costs that result from inefficient practices, systems or controls." In a similar vein, Baran (1959) defined waste as the difference between the level of output of useful goods and services that would be obtained if all productive factors were allocated to their best and highest uses "under rational social order," and the level that is actually obtained. McKinney reminds us that waste is unnecessary, which is to say avoidable, but fails to explain what he means by inefficient or ineffective. Stanbury and Thomson (1995) warn that eliminating waste is costly; it would, therefore, be wasteful to try to eliminate all waste. Baran adds that waste is gauged by the gap between what we acquire of the things we want and what we could acquire. Stanbury and Thomson (1995) explain that the term waste derives from the Latin uastus, meaning to ravage, to leave desolate, or to fail to husband or cultivate. Hence, of the varieties of waste, 'technical inefficiency' is probably closest in meaning to traditional usage. 'Technical inefficiency' simply means that the managers of an entity fail to minimise cost or maximise output because they are not using the best technology available.

From yet another non-technical point of view, McHale (2000) wonders which bodily parts and products can be legitimely regarded as 'waste.' As well, Hollander (1998), a sociologist, provides an interesting addition to defining waste as something that "needs to be expelled in order that the system continue to function."

The question posed by Gourlay (1992) was, 'what, then, is waste?' Is there such a thing, or are there only different wastes? Are there features common to all wastes that justify one designation, and also suggest a common solution to the problems they pose? Ellwood and Patashik (1993) blithely assert that waste, like beauty, is in the eye of the beholder. The essence of the European Council's definition is that the owner does not want it; thus waste exists only where it is not wanted. Some other definitions also explain why the owner does not want it. A proposed definition for waste by Lox *et al.* (1995) was:

"[...] either an output with ('a negative market') 'no economic' value from an industrial system or any substance or object that has 'been used for its intended purpose' (or 'served its intended function') by the consumer and will not be re-used."

The second half of this definition suggests that the product was designed for one single purpose, and as soon as the purpose was fulfilled, it turned to waste. It may be still functional, but it is not used anymore, nor re-used, and one does not know the reasons why. It may also mean that the product lost its original properties and cannot fulfil its function anymore. On the other hand, the first half of the definition suggests that waste is a substance that no one ever wanted: it was created to be a waste. The obvious question comes to mind, why? The problem with most of these definitions is that they also do not really suggest that creating waste should be avoided. This is known, but the definition does not point out this fact. Indeed, it seems acceptable to toss away something no longer wanted, or to create something with no use at all.

Yet, there are other types of wastes. Gourlay also exemplifies the dollop of mustard left on a plate, which is neither useless nor has it lost its properties. It became waste because the owner failed to use it. In other cases, *e.g.* agricultural production, or fish farming, those substances that fail to reach their target and go beyond (nitrates leaching into soil, food and chemicals fed to fish ending up at the bottom of the sea), are wasted not because the owner has failed to use them, but because he used them in excess, and thus failed in the usage for their intended purpose. Both of these waste types defy the "things that the owner disposes or wants to dispose of" types of definition. Did the fish-farmer have any intention of disposing of perfectly useful fish-food? Did the farmer want to dispose of totally serviceable fertiliser? Clearly not. However, the fish food dispersed to the bottom of the sea; fertiliser washed down the watercourses is certainly wasted, unavailable for the fish/plants, non-retrievable by any means. Why did it then become a waste? Gourlay suggests that a working definition for waste could be: "Waste is what we do not want or fail to use" (Gourlay 1992).

This is, again, a human-related definition, and does not appear to properly explain the concept of production wastes, for instance. By-products are not necessarily created from carelessness, they are often unavoidable. We are aware that when aiming at a product, it may inevitably involve the production of certain by-products, wastes, emissions, and some of them cannot even be captured. It is not about that they are not wanted, it is rather that they are inevitable, and/or a way could not be found to make use of them. Consider the waste heat of electricity production: it is absolutely in the best interests of a power-plant to raise efficiency and, if it was up to them, every bit of thermal energy would be transformed into electricity. Unfortunately, the technological level is not on par to realise

this. Heat is wasted not because the power plant does not want it, or fails to use it, but because there is no possibility to avoid it.

When classifying waste, more often we end up classifying it by its origin/source: wastes from energy conversion; processing waste; wastes from emission treatment; cleansing wastes; household wastes; packaging wastes; demolition and construction wastes, *etc.*, *etc.* Or by some of its characteristics as hazardous waste or biogenic waste; many smaller piles are created from a large one, while the whole concept of waste has gone astray. Rather, let us classify waste by the reasons of its creation. Table 6 gives the general lexical entries for waste from *Webster*'s and *Cassell* dictionaries.

Table 20. What is waste? (Webster's and Cassell dictionaries).

Lexical entry	Definition	
Waste (verb)	to consume, to spend, to use up unnecessarily carelessly or lavishly; to fail to use to advantage; to wear away gradually; to devastate.	
Waste (adjective)	something superfluous, left over as useless or valueless; desolate, desert, unoccupied, uncultivated, devastated, barren; having served or fulfilled a purpose, no longer of use.	
Waste (noun)	the act or instance of wasting of throwing away; gradual diminution of substance, strength, value; material, food, etc. rejected as superfluous, useless or valueless; material produced by a process as a useless by-product; an unusable product of metabolism; anything unused, unproductive, or not properly utilised; anything left over as excess material; by-products not in use for the work at hand; that which is of no value; worthless remnants; refuse, damaged, defective, or superfluous material; material rejected during a manufacturing process; an unwanted by-product of a manufacturing process, chemical laboratory, or nuclear reactor; refuse from places of human or animal habitation.	

Therefore, to formalise the classification of waste by the reason of its creation, the author of this thesis has chosen the PSSP³ modelling language as an effective tool to present waste classes with semantic clarity. When 'translated' to the PSSP language, there is an evident pattern, and these entries can then be organised into four distinctive classes. Hence, in the next section a description of the framework of the PSSP language is introduced.

^{3.} PSSP is a trademark of Nordem company.

4.6 The PSSP language

The acronym PSSP stands for Purpose, Structure, State and Performance, which are object attributes, as this language is devised using object formalism. PSSP is a generic concept framework, introduced by Professor Veikko Pohjola, and has been used for over ten years in research at the Laboratory of Chemical Process Engineering at the University of Oulu, Finland, for systematising process development (or conceptual process design), and for creating the associated concept system.

For many years, object orientation has been associated with a particular kind of programming language. Today, however, the notions employed by object-oriented programming languages are applied as a general modelling philosophy. Conceptually, object orientation is a way of organising our thoughts about the world. This organisation is based on the types of things – or object types – in our world. Object-oriented analysis models the way people understand and process reality - most importantly through the concepts they acquire. The formalism implies, in particular, that the aspects of a real thing, which are regarded relevant, are explicitly named beforehand and anything to be said about the real thing will be said about those named aspects, called attributes. (Martin and Odell 1995.) Modelling efforts reduce significantly if there is a list of attributes available and especially if it is known that the list contains all the relevant attributes and only those. Suppose that a conceptual model for process X is needed, and that there is the generic model available in the object format. The latter model (as a template) then provides the modeller with the proper list of attributes, and the modelling activity can be focused on searching for that domain knowledge which is required for obtaining the satisfactory values of the attributes. (Pohjola 1997a.) How far is it possible to advance in modelling the world in generic terms? To answer this, the following sub-division of saying anything about the world is useful (Ibid.):

- 1. About what to say? (Object)
- 2. With respect to what (which aspect) to say? (Attribute)
- 3. On the basis of what (which knowledge) to say? (Relation)
- 4. What to say? (Value)

There should be no principal obstacle for building a hierarchy of object classes with prefixed sets of attributes, which is sufficient for modelling all the things. PSSP is a formal modelling language having certain unique features not to be found in other modelling languages. The distinctive features stem from the ontology behind the language (Pohjola & Tanskanen 1998, Pohjola 1999).

Ontology is the 'science of being as such.' The original treatment stems from Aristoteles in the books entitled 'meta ta physika.' Due to this origin the term 'metaphysics' is often used to indicate ontology. The root of ontology is the conviction that we humans live in two worlds simultaneously: a material world of tangible objects and observable facts, and a mental world of images, thoughts, opinions and impressions (Eekel 1997). These two worlds are in continuous interaction with one other. An ontological commitment can be seen as a set of meta-level decisions, which reflect the modeller's personal comprehension of what is a fruitful way to view the world. It does not have a truth value and thus cannot be judged on that basis; what matters instead is its utility. In fact, every human being commits himself to a certain concept system when

modelling, but usually this is done subconsciously. When building a theory, and on that basis the generic model - a methodology - for how to manipulate reality, this concept system must be made explicit. The development the PSSP language is based on the following ontological commitments (Pohjola & Tanskanen 1998):

- 1. The world is made of real things and abstract things. The real things are all what we can build conceptual models for. The abstract things are what we use to specify properties of real things. All the real things can be viewed as descendants of the generic real thing. The notion of the generic real thing is the cornerstone of the PSSP language. It entails that all the real things can be modelled using a unified format, which is inherited from the generic real thing. Representation of real things thus forms a tree-like inheritance hierarchy. Notable here is that human activity is viewed as a real thing to be represented in the same inheritance hierarchy as the things to be acted on.
- 2. The generic real thing can be formalised as an object having four attributes: Purpose, Structure, State, and Performance. These four attributes form a necessary and sufficient set for describing all the properties of any real thing. The commitment to object formalism leads to a natural and powerful way of describing reality. If the real things are classified into artefacts and natural things, the attributes Purpose and Performance may sound redundant for the latter. However, it is possible for a natural thing to turn into an artefact and vice versa. The belonging of a real thing to either sub-class can then be decided on the basis of whether it is possible to assign a value other than "unspecified" to these attributes. For instance, a human being as a natural animate thing can be assigned a purpose and a performance in an organisation as soon as he/she is subjected to education and utilisation by that organisation.
- 3. The structure of a real thing has two dimensions: the topological structure and the unit structure. The topology of a real thing can be modelled as a set of objects (nodes) belonging to the same class as the original object and a set of relationships (links) between the nodes. The unit structure of a real thing can be modelled as a set of objects (parts) belonging to classes other than the original object class and a set of relationships (links) between the parts. Structure has a specific role among the attributes. The structure of a real thing becomes specified in terms of other real things instead of abstract things. The attribute offers for the concept hierarchy two directions for expansion. Describing structure in the two dimensions can be argued to make it possible to describe the structure of any real thing with any degree of detail no matter how complex the structure may be. Representation in the two dimensions is rich enough for modelling structures at any level of detail. The links in the two structural dimensions are expressions, which are usually in the form of relation models and represent temporal, spatial, and causal relationships between states (state variables) of the structural sub-objects.

The highly unified format makes the PSSP language a powerful object-oriented modelling tool. It combines a syntactical simplicity and semantic clarity with representational richness. It is not domain specific and thus ideally suits to the integration of knowledge from different disciplines. (Pohjola & Tanskanen 1998.)

For the purpose of re-defining waste, it is very useful to model the waste 'things,' as objects with these four attributes (point 2), and define the values of those attributes. Structure and State are relatively straightforward to define for the concept of waste. After careful analysis, one can realise that the values for Purpose and Performance are what distinguish wastes from non-wastes. Man-made things are often referred to as artefacts. An artefact may be defined as something that has been intentionally made or produced for a certain purpose (Hilpinen 1999). They have thus been ascribed a Purpose, and are expected to have a Performance with respect to the assigned Purpose. Performance is evaluating the 'goodness' of the object with respect to the Purpose. As for some waste, it is questionable, that they have been created intentionally, or if they have any purpose at all. Other waste things are waste because they are not performing anymore. To such extent, the PSSP language inspired a new way of classifying and, ultimately, defining waste.

4.7 Re-defining waste

Looking at the descriptions (or definitions) of the lexical entries in Table 20, one could view them in terms of the PSSP language. We can see that all of these things have some flaw in their Purpose or Performance attribute. More precisely, any of these entries can belong to one and only of the four waste types listed in Table 21.

Table 21. Classes of waste (Pongrácz & Pohjola 1997).

1.	Non-wanted objects, created not intended, or not avoided, with no purpose	Into this group belong outputs with negative market value, non-useful by-products, emissions, processing and process wastes, cleaning wastes, <i>etc</i> .
2.	Objects that were given a finite purpose, thus destined to become useless after fulfilling it	This is the group of single-use products: most packaging, single-use cameras, disposable diapers, <i>etc</i> .
3.	Objects with well-defined purpose, but their performance ceased being acceptable	Obsolete products, old furniture, discarded household appliances, non-rechargeable batteries, demolition wastes, <i>etc</i> .
4.	Objects with well-defined purpose, and acceptable performance, but their users failed to use them for the intended purpose	Spoiled products, products used in excess, products that go beyond their target, or simply products that the owners do not wish to own anymore. They could be perfectly useful, they are waste solely due to the holder's wrongful action, and often are non-retrievable. This class embodies the essence of wastefulness.

The basic hypothesis towards building the theory of waste management is that a thing is waste because it has no Purpose; or it has fulfilled its Purpose; it is not used or not usable for its Purpose, because its Performance is inadequate; or because their owners failed to

use, or did not intend to use, them for their assigned Purpose. Based on this, waste can be defined as:

Definition 1 Waste is a man-made thing that has no Purpose; or is not able to perform with respect to its Purpose.

This waste definition does not include being 'discarded,' it highlights that being 'waste' is a temporary state. This description allows for the possibility of the waste being turned into a non-waste. In fact, it *calls for an action* to turn the waste into a non-waste. A waste description of a type: "a thing what its owner has discarded" (and eventually sent to landfill) deprives the thing of the possibility of ever being useful again.

In response to the requirement that "the waste definition shall point out the fact that creating waste is bad," some examples follow. The description of waste as "a thing, which the owner failed to use for its intended Purpose," highlights the fact that it was because of the wrongful action of the owner why the thing became waste. When we describe waste emission as "a thing to which its producer has not assigned a Purpose," we point out the error of the producer. While a waste of the type: "thing which is not performing in respect to its original Purpose due to an irreversible damage in Structure" explains the reason why the thing became waste.

Wastes of the class "no Performance, because the owner fails to use it for its Purpose" perhaps sounds too restricted. One might ask that, why would a perfectly useful thing be considered waste? Suppose that the manager of a company is taking an inventory of stock. The inventory finds spare parts in stock such that nobody remembers their Purpose. Probably the machines they apply to have been replaced long ago. Some long-time worker may still remember what they are good for; still, almost certainly, this company will throw away these spare parts because they have no Purpose for them. For a company who still has the machines they apply to, these spare parts are very useful. To the company that does not have the machines any longer, the spare parts are just a dead component of inventory.

This example also illustrates the dynamism of the concept of waste. The same thing may be waste or non-waste for different persons: for one who knows what it is good for *versus* the one who does not; in different places: in a company that owns the machine it applies to *versus* the one that does not; and different times: in the times the company still owned the machine *versus* when it no longer owns it.

4.8 Defining non-waste

It is justifiable by legislation to prescribe conditions to handle potentially hazardous material, but there should not be an obstacle to resources conservation because of a material being labelled 'waste.' To this end, it is useful to define the concept of non-waste. By explaining why something becomes waste, waste as defined by Definition 1 intrinsically offers a solution as to how a waste object can be turned to non-waste again (assuming that it is retrievable). Quite simply, a waste can be turned to non-waste if it is

given a new purpose and/or will be used for that purpose. Thus, we can define non-waste as:

Definition 2 Non-waste is a thing, which has been assigned a Purpose by its (or a potential) owner, and this owner will either use it for that Purpose, or by adjustment of State or Structure, ensures that the object will be able to perform with respect to the assigned Purpose.

Figure 13 illustrates a flowchart of deciding whether a thing is waste or non-waste based on the above considerations.

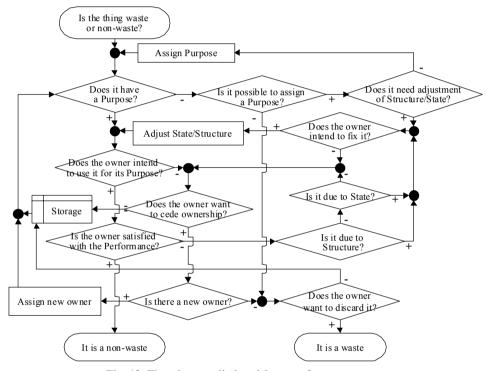


Fig. 13. Flowchart to distinguish waste from non-waste.

The expected Performance may require changes of State or Structure. Granted by their ownership, owners have the right to do so – manipulating Structure or State – and it should be their responsibility to decide the how. State also represents functionality. As an expectation of responsible ownership, the figure includes the possibility that even though the owner wants to cede ownership, in the lack of a new owner, he will not dispose of the thing. However, after long storage it may be necessary to review the Purpose and functionality of the thing, as illustrated earlier with the example of aged spare parts. Things covered by Definition 2 will not be considered waste, and should be exempt from restrictions regarding wastes, as in the Basel Convention (European Council 1993a), which limits international flow of hazardous residuals. Materials so regulated cannot compete with 'virgin' materials, so in a form of a self-fulfilling prophecy, being listed as

waste under such programmes ensures that the materials will, indeed, become waste and not be recovered. While recovery is encouraged by Community regulation, ironically, it is precisely the environmental regulation that reinforces linear flow of materials throughout the economy.

4.9 The position of the metallurgy industry

The Finnish economy, particularly some sectors of export industries that sustain national affluence, is strongly based on exploitation of natural resources and fossil fuels. Compared to Finland's level of industrial production, reserves of metal ore are relatively small, and known ore reserves are rapidly being exhausted. To the extent that environmental impacts are the consequence of the magnitude of total material input into production in an economy, they can be lessened by reducing the use of materials – by concentrating on what has been called qualitative growth. The least growth of material consumption has taken place in the basic metals sectors. (Hoffrén *et al.* 2001.) Traditionally, materials use is summarised as extraction of raw materials from the environment, using them for a certain purpose, and finally discarding and returning them to the environment in the form of waste (Joosten *et al.* 1998).

Herlitz (2000) calls for a clearer definition of waste so that fully recyclable materials, such as iron and steel scrap, are not classified as waste. To do so, a clearer definition would define 'treatment' and 'recovery,' or 'utilisation,' 'residue' and the content of 'waste' more precisely. Lorber (2000) points out that this is not purely an academic question, industries increasingly feel the effect of definitions.

The Finnish concern, Rautaruukki Group, uses approximately 1.34 million tonnes of post-consumer steel scrap in its production yearly. Scrap accounts for over 20 % of Rautaruukki Raahe Steel factrory's iron-ore and blast-furnace based production's input (Pietilä 2001) of the raw material. In the year 2000, 46% of steel produced in Europe was made of scrap. In Finland, there are hundreds of scrap dealers who generally sell the collected scrap to the Kuusakoski Oy company for treatment. The company then sells the scrap forward to companies that are in the best position from the logistics point of view.

Szekely argues that due to easy recyclability of steel, and the steel industry's capability to utilise other wastes, such as plastics to reduce heavy fuel need, and also its own marketable wastes such as slag, the steel industry is an ideal partner in Industrial Ecology networks. He also proposes that steel is a green material. (Szekely 1996.)

In Europe, every year, nearly 12 million tonnes of steel slag are produced. Owing to the intensive research during the last 30 years, today, 65% of produced steel slags are used for different fields of application. In Germany, as much as 97% is utilised (Motz & Geiseler 2001). A research study in the development of high performance cementing materials concluded that blast furnace slag, steel slag, copper slag and phosphorous slag exhibit not only higher early and later strength, but also better corrosion resistance than normal Portland cement. In addition, the production of Portland cement is an energy-intensive process, while grinding of metallurgic slag needs only approximately 10% of the energy required for the properties of Portland cement (Shi & Qian 2000). Consistent

with the long-term experience of products of steel and blast furnace slags, they have been removed from the European Waste Catalogue (EWC) lists (Motz & Geiseler 2001).

In Finland, 70 million tonnes of natural mineral aggregates are used each year for road construction and earthworks (Mroueh *et al.* 2001). Depletion of resources, the need for resources conservation and lengthened transportation distances called for the use of substitute materials. For over 30 years, fly ash and blast furnace slag has been used in earth construction (Mroueh & Wahlström 2002). In the case studies conducted by VTT Chemical Technology, it was found that blast furnace slag reduced the environmental loading when compared to the use of natural aggregates (Mroueh *et al.* 2001). Table 22 comprises the annual utilisation of the metallurgical industry by-products in 1998-1999 (Mroueh & Wahlström 2002).

Table 22. By-products of metallurgical industry in earth construction in Finland, 1998-1999 (Mroueh & Wahström 2002).

	Production Amount used in earthworks		Usage	
	t/a	t/a	%	
Blast furnace slag				
-un-ground sand & slag	550 000	200 000	36	Road constructions.
-ground slag		120 000	22	Binder in soil stabilisation.
Slag from LD steel				
production	170 000	85 000	10	Asphalt aggregate.
Slag from ferrochrome production	290 000	290 000	100	Road and field construction, foundations.
Foundry sands	130 000	n.a.		Insulation structures.

The environmental legislation does not refer to the term by-product. Habitually, the industrial by-products and recycled material are regarded as waste. According to the Environmental Protection Act, an environmental permit is required for an institutional or professional utilisation of waste. A permit is granted by the local environmental authority if the amount of waste being used is less than 5 000 tonnes. For larger amounts, the permitting authority is the regional environmental centre. Usually it takes more than four months to obtain the permit. The long and complicated permit process is one of the largest barriers impacting the use of industrial by-products. (Mroueh & Wahlström 2002.)

Since the beginning of 2002, a 'slag-war' has started in Finland, when North Ostrobothnia's Environmental Permit Office issued a judgement that steel and ferrochrome slags of Tornio's AvestaPolarit are considered as wastes (Jurvelin 2002a). In Tornio, 300 000 tonnes of slag are produced, annually. However, the largest slag producer is Rautaruukki Raahe Steel factory, which produces 750 000 tonnes yearly (Jurvelin 2002b). This is equal to over 51 (40 t) truck-loads of slag per day!

The arguments surrounding slag have driven the Ministries of Trade and Industry, and of the Environment into a dispute. The Ministry of Trade and Industry does not accept the understanding of environmental authorities that ferrochrome slag would be waste; they see it as a by-product. (Jurvelin 2002b.)

This argument has arisen from the legal definition of waste: "any substance which the holder discards or is required to discard." According to Finnish environmental authorities, it does not matter if this waste is utilised, or not. "It is against engineering logic," Jurvelin

(2002b) quotes Ms. Salonen of the Ministry of Trade and Industry. As discussed earlier, Advocate General Jacobs of the ECJ agrees with the Finnish environmental authorities. Given that the current legislation on waste leaves much room for interpretation by competent authorities, many arguments end up being referred to the ECJ (Bontoux & Leone 1997). However, the Advocate General stated that it must be, to some extent, left to Member States to develop more detailed criteria to apply the term 'recovery operation' and the national courts can apply the Directive to the potentially large number of borderline cases, which may arise in the practice. The role of the Court should be limited to providing national courts with the interpretative guidance which they require (Purdue 1998). Finnish authorities may thus decide whether scrap and slag are 'recovered' or 'utilised.'

SKJ-yhtiöt Oy, a subsidiary company of Rautaruukki Steel, specialises in upgrading and marketing the by-products of steel production. In 2001, SKJ-yhtiöt Oy handled about 2.92 million tonnes of by-product slag from steel production which is utilised as raw material for various uses, *e.g.* building materials industry, road construction and soil improvement. SKJ upgrades and markets almost all the steel industry by-products and. (SKJ 2002.) Slag is processed – crushed, screened, metals removed – in processing plants to provide the products required. Metals that are separated from the ferrochrome slag in the ferrochrome enrichment plant are used as pure ferrochrome in the stainless steel making process. Most significant in industrial sales is water quenched (granulated) and blast furnace slag, which are sold as a raw materials for the cement industry. As well, crushed, air-cooled slag products are sold for use in the building materials industry. (Rautaruukki 2001.)

Slag offers a number of advantages in road construction as compared to traditional materials. As a case in point, according to SKJ Oy, blast furnace 'sand' used for road construction replaces twice the amount of crushed stone otherwise used. Metallurgical by-products are also superior to natural materials in their thermal insulation and bearing capacity. For instance, when using SKJ Oy's Okto brand-named product as frost protection around pipes, the pipes do not have to be placed as deep as when natural sand is used for insulation, and there is no need for separate insulating (*e.g.* plastic) material. (Personal Communication 26. 08. 2002.)

However, if, according to the environmental permit, slag is to be treated as waste, it will result in greater expenses for its handling, and may ensure that marketing prospects would be very problematic (Jurvelin 2002a). Steel factories are fearful that the decision of the environmental authorities would destroy the slag market, as the 'waste' label may discourage potential customers and it would lead to a web of permit red tape – and bureaucracy around the slag market. Steel scrap, extensively used as raw material of steel making – Imatra Steel uses 100% scrap as raw material – was also given the 'waste' label. Labelling scrap metal as waste makes metal recycling difficult, as scrap collectors and dealers would become waste handlers, and scrap is to then be stored as waste (Jurvelin 2002a). According to the environmental authorities, the waste law should only entail regulation and control, not insurmountable difficulties (Jurvelin 2002b). Nevertheless, legislation should support any activity to turn wastes into non-wastes rather than hinder them. It is a controversy that while the definition is so fixated on the notion of 'discard,' the legislators wish to call something a 'waste' when it is *not* discarded, neither do the owners intend to discard it: they wish to sell it.

Slag has multiple Purposes in steelmaking. It absorbs unwanted impurities from the metal, provides heat insulation to the molten metal as well as prevents the interaction of molten metal with ambient atmosphere in the ladle, *etc.* (Mattila.) However, after the metal is drained from the ladle, slag has fulfilled its Purpose, one could thus argue that it is waste of Class 2 (see Table 21). It is, however, possible to assign a new Purpose (use in construction) and there is an actor (SKJ) who intends to adjust its Structure and State to make it fit to Perform with respect to that Purpose. Applying Definition 2 to slag, we can say that there is a potential owner for slag (*e.g.* a construction company) and by grinding, screening and removing metals, slag is turned into a marketable product that is able to Perform with respect to the Purpose assigned by its new owner. Slag treated this way is thus a non-waste and can be referred to as a usable by-product.

In the case of scrap, we can say that scrap is waste only for the previous owner, who has disposed it because it did not Perform satisfactorily for its Purpose, it was thus waste of Class 3 or 4. Again, there is a potential owner for the scrap — any metallurgical company — who wishes to give it a new Purpose (re-melt for metal making). There is also an actor (Kuusakoski Oy, for instance) who intends to adjust its Structure and State (collect, screen, separate), thus making it fit to Perform with respect to the Purpose to which it is to be assigned. Scrap directed for re-melting, is thus not a waste either, at best it is a secondary raw material.

In summary, despite its *explicit* wish of waste prevention/reduction, when according to present legislation a thing is assigned the label of a 'waste,' it is going to be treated like waste, *implicitly* legislation thus amasses waste. The suggestion in this thesis is that being 'waste' is only to be viewed as a temporary state and a *challenge* to turn it into a non-waste. Efforts ought to be allocated to this task.

4.10 The hazard of waste

Hazardous waste, or the hazard of waste, is somewhat of a misconception. A substance is not hazardous just because it is waste. As we have already considered, a thing is waste due to a fault in its Purpose or Performance attribute, while 'hazard' of a material comes from its Structure or State. If a substance is considered hazardous, it usually refers to contact with a human being: it can cause undesired effects on the human body. This is irrespective of whether it is called 'waste' or not. Consequently, a spent solvent is not hazardous because it is waste, it was just as hazardous when it was not yet waste. Ideally, we ought to reduce the usage of a hazardous substance, or substitute with a less harmful one. This issue would be raised, however, before any hazardous substance is used, not only when it becomes waste; and hazardous substances shall be handled with care at any point of their life-cycle. (Allenby 1999.)

When discussing the definition of waste, Cheyne and Purdue (1995) ask why there should be a special regime for waste, and what distinguished the problem of waste from the problem of pollution. They concluded that pollution is always caused by waste, but waste does not always cause pollution, and assert that the problem of waste is the risk that if not appropriately dealt with, will cause pollution. It is easy to defy both claims that all

pollution comes from waste as well as that if not dealt with, waste will cause pollution. As concluded by Allenby (1999):

"The purpose of an integrated material policy should be to ensure safe handling of all materials regardless of where they are in their life cycle, and to regulate every material equally, regardless of whether it is virgin or originates in a residual stream, according to the actual risks involved."

It is a somewhat different issue when the hazardous substance is a newly-arising compound from an industrial activity and is considered waste. For example, dioxin emissions are non-wanted emissions, created with no Purpose, thus they are a waste and they are hazardous: but it is not hazardous just because it is waste. It is hazardous, *and* it is waste and, ideally, their creation has to be avoided.

Tromans (2001) argues that there is a need to consider the fundamentals that are involved in regulating waste, as opposed to substances which may have equally harmful consequences in their use. Why should different principles apply to the transport of chemical feedstock and the same chemical waste, given that the consequences of it spilling into a roadside ditch may be equally serious. Another problem is also that there are no obvious criteria to distinguish hazardous from non-hazardous waste. This debate continues on the appropriate reconciliation of principles protecting free movement of goods, and restrictions of trans-boundary shipments of wastes and recyclable materials (Smith 1993). A waste may have equivalent hazardous properties to a raw material in terms of toxicity, flammability, and so on. Tromans explains that in the case of the raw material, the economic incentive is to use it efficiently and to treat it accordingly. The objective is to incorporate as much of it as possible into the product, not into the environment. Once the material became waste, however, the economic imperative is to dispose of it as cheaply as possible. Tromans asserts that the risk of the hazardous properties causing harm has increased - particularly if the least expensive method involves its immediate re-assimilation into the environment, rather than recovery and reuse. In other words, it is the economic context rather than the hazardous properties which gives rise to the unique risk attached to waste in this comparison (Tromans 2001).

To reiterate, the author of this thesis would like to highlight the issue that waste in itself is not detrimental, but the act of wasting *is*.

5 The ownership concept and awareness of waste

"The problems of the world that we created as a result of our thinking this far cannot be solved by the level of awareness that created them." – Albert Einstein

Artefacts can be defined as results of design (Pohjola 1997). The life of an artefact begins when a human being defines the Purpose and the expectations of the Performance. Based on these, the Structural specifications are designed. A natural thing can also become an artefact when a Purpose has been assigned to it. In the previous chapter, the concept of an owner was frequently mentioned. Humans often claim ownership over artefacts and use them for their Purpose, but cede this ownership when they are dissatisfied with the Performance of the artefact. Artefacts unable to perform with respect to their Purpose and abandoned by their owners have been defined as wastes. The artefact's life ends when its Structure is disintegrated and it is no longer recognisable as an artefact. When an artefact is no longer recognisable as such, it is a natural thing. 'Artefact' and 'waste' are both human constructs, since humans assign Purpose and humans evaluate Performance. We can recognise three basic relation types between humans and artefacts.

- Designer-type of relation: The designer proposes Structural specification based on assigned Purpose and expectations of Performance.
- Producer-type of relation: The producer is the one who is first assigns a Purpose to the artefact, and can have some expectation of Performance as well.
- Owner-type of relation: The owner evaluates the Performance of the artefact. It is also possible that the owner assigns a new Purpose to same.

Waste is a humanly created thing, there is no known waste in the cycle of nature. Hence, in the following, only ownership of artefacts will be discussed, to wit 'ownership' is to be understood as individual/private ownership. Ownership in waste management is a rather ethical issue. The institution of ownership has conceptual and practical implications when ecological concerns are taken into account (Oksanen 1998). It involves the ethical considerations of what one is allowed to do with one's property, but the interest of the author of this thesis is in ceding ownership and its implications on waste management.

5.1 The concept of ownership

This chapter will deal with the concept of ownership in waste management. It is not a study of the institution of ownership, only its implications on waste management. It was the fourth sub-class of waste (see §4.7, Table 21) that triggered the analysis of the implications of the concept of ownership on waste management, and was recognised as having a particular importance in waste management. As discussed in the previous chapter, the definitions of waste indicate that waste is simply 'a thing that has been disposed of by its holder or owner.' The reason for disposal generally is that the Performance of the artefact ceased being acceptable (waste Class 3), or because the artefact has fulfilled its finite functional specification (Class 2). In contrast, waste of Class 4 is a thing with a well-defined Purpose, and with its Performance acceptable with respect to that Purpose, but for some reason, the owner did not wish to own it any longer. The artefact turned to waste simply because its owner gave up ownership.

It may then be argued that waste is simply a thing without an owner. Wastes of Class 1 were, however, never owned in the true sense of the word. Wastes of this class are nonwanted by-products, and the producer may not even be aware of them. Being the producer of a thing, however, also implies a type of ownership. It was proposed that for the purpose of usage in waste management, 'ownership' be defined as (Pongrácz & Pohjola 1998):

Definition 3 Ownership over a thing can be defined as a right and a responsibility to act upon the thing that is, to manipulate the properties of the thing.

Manipulation is not to be understood in its negative connotation, but rather as to adjust, change, manage or use. The owner has the right to use the thing he owns, and change its properties if desired. It must be remarked upon that, for instance, if we are to change the purpose of a thing, we are actually not physically manipulating the thing, only changing its Purpose attribute. Given that the producer, who created the thing, also created its properties, which can be seen as a form of manipulation, resulting in the producer being delineated as the 'owner.' Of waste Class 1, the producer usually cedes the ownership rights after the thing (e.g. waste emissions) has been produced.

5.2 The ownership concept expressed in PSSP

Summarising the preceding, an ownership relation is involved in producing the thing, finding the thing useful, intending to make use of the thing, and using the thing. Table 23 summarises these concepts expressed in PSSP language.

Table 23. The ownership concept expressed in PSSP (Pongrácz & Pohjola 1998).

Producing the thing → Specifying the Structure of the object.

Finding the thing useful → Assigning the Purpose of the object.

Intending to use the thing → Having an expectation of the Performance with respect to the Purpose.

Using the thing → Adjusting the State and evaluating the Performance of the object.

When an artefact is designed, the time frame is assumed during which the performance of the artefact is guaranteed. The performance of complicated artefacts depends on the performance of structural parts. Usually, the performance of an artefact ceases as soon as the performance of a part ceases. It is the designer's task to assess the risks and benefits whether to replace the non-working part, or the whole artefact. In the event that the whole artefact is declared waste, it may still contain structural parts that have acceptable performance. It can, again, be the designer's task to determine how the working structural parts can be re-used in their present state, or whether the constituent materials should or could be re-used. In any case, the designer can only give suggestions for further action, but acting accordingly is the owner's responsibility. (Pongrácz & Pohjola 1998.)

5.3 Ownership and defining waste

Palmer (2001) proposed the following definition for waste: "A waste is any object whose owner does not wish to take responsibility for it." This definition is also of the type that depends on a relationship between the person, who has the function of owner, and the thing. Palmer argues that, without an identified owner, no item can be discussed as waste or not, and, as a default position, states that anything without an owner is a waste. He argues that if it is potentially valuable, an owner will emerge, until then, it behaves like any other waste. He discusses the case of a bottle lying by a highway. It is the relationship of the bottle to its last owner that controls in the primary instance, and its relationship to its next owner which then takes over. In between owners, it is a waste. The author of this thesis is in accord with this observation.

For purely arbitrary purposes, Palmer imputes a previous owner to be an unknown passer-by, who tossed the emptied bottle out of a car window. His point is that, by assumption, an owner did exist who decided that he no longer wanted to take responsibility for the now-empty bottle. The author of this thesis now wishes to add that this decision occured due to the fact that by emptying the bottle, it had fulfilled its single finite Purpose, thus it had no Purpose for the owner anymore. Palmer argues that at the point when the decision to discard was made, the bottle became waste. One would argue that the bottle became waste the instant it no longer had a Purpose for the owner. The bottle, not retained by its responsible owner, thus rests by the roadside. Several prospective fates can result. A transient person, to whom the residual value of the bottle is significant, may pick it up. In this case, a new owner with a new relationship is substituted with respect to the former waste. In Palmer's opinion, the bottle is no longer a waste when a new owner assumes responsibility. One would add that the new owner had done so because he had found a Purpose for the bottle: either to fill it, or return it for deposit. Contrarily, Palmer continues, when the bottle is found by a clean-up crew, their job being to collect waste, they thus take no personal, or formal responsibility for each item. No new owner is to be inserted into the definition: waste remains waste until it 'lands in a dump' – argues Palmer. It is essential that attention is given to the following point. In several countries, according to their respective law, if the waste management company collects the waste, it is their property. Hence, by law, the waste thing has an

owner. However, it could be argued that it is still waste, and it is so because no new Purpose has been assigned to it.

According to Palmer's definition, any object, which acquires a new owner, who wishes to take responsibility for it, is not a waste, no matter what its history. As a case in point, if a drum of pyridine (a chemical solvent) is purchased for special use by a non-chemical company, it is a valued inventory item, and not a waste by anyone's standard. Over time, if the anticipated use does not materialise, and if the drum is allowed to deteriorate outdoors, losing its labelling and markings, so that no one retains any knowledge of its contents or uses, then the drum of pyridine becomes a waste. Palmer argues that it is a waste because the owner no longer takes responsibility for the drum. One would then argue that the pyridine in question is waste because it has no Purpose for the owner, and the wish to cede ownership and responsibility is a consequence of this. However, when a regulator from the Health Department observes the drum, and establishes that it is apparently a noxious, unknown chemical, they will compel the company to take responsibility for it. Palmer argues that it still remains a waste since the definition hinges on the desire to take responsibility, not the taking of responsibility in itself. It is the desire, based on a perception of utility for the material, which controls future behaviour, not the responsibility itself. This author agrees that the drum of unidentified chemical is still a waste for the company, but it is so because it has no Purpose for them. A major point to observe is the manner in which this pyridine waste may become a commercial item once more. All that is required is for a chemical recycler to take a sample, analyse the contents and re-establish its identity. A new owner can be assigned now, for whom the chemical has a Purpose - thus it will turn to a non-waste. Palmer (2001) notes that the process of turning the waste into non-waste requires no physical handling, purification, or remanufacturing of the product itself, simple identification serves the purpose of a new owner.

Based on the above, it is the presumption of the author of this thesis that ownership alone cannot define the concept of waste. Ownership is important in relation to handling waste, or 'waste management' would be more *à propos*, but to define waste, the value of the Purpose attribute needs to be known.

It can be argued that waste can be recognised either as 'a thing with a given Purpose but without an owner,' or simply as 'a thing without a specified Purpose.' Waste as expressed in Definition 1, can be defined in relation to human beings as follows:

Definition 4 Waste is a man-made thing that is, in the given time and place, in its actual Structure and State, not useful to its owner, or an output that has no owner, and no Purpose.

This definition also illustrates the dynamic nature of waste. The same thing may be waste or non-waste for different persons, in different places or at different times. This also reflects, that with respect to human beings, waste can be defined only temporarily, since even the same person may find a (re-)use for the thing in the future. Definition 4 also offers greater possibility for a waste to be turned to non-waste, if waste was simply defined as "something the owner does not want."

5.4 Ownership in waste management

Producer-responsibility initiatives generally refer to the responsibility of manufacturing industry to reduce their resource use as well as to recall, for recycling, waste materials which result from their products. While the idea of moves that require industry to take back materials after use appeals to both governments and the public alike, the term should be broadened in its application.

The general public is also a waste producer. One of the principal reasons behind charging schemes for waste collection from households is to engender public awareness of the amounts of waste they create. This, in turn, is based on the principle of shared responsibility, as the European Community's strategy for waste management (European Council 1997) states that all economic actors, including producers, importers, distributors and consumers, bear their specific share of responsibility with respect to the prevention, recovery and disposal of waste.

5.4.1 Ownership and awareness

Improving the recycling rate might be the primary objective of recycling targets, but effective diversion from disposal can be achieved in different fashions. Public participation is, obviously, critical to success, however, it is not just *how many* people participate, but *how well* they do so, which is significant (Thomas 2001). Thomas then questions how to best improve understanding, and thence participation. Publicity, information and education will, no doubt, affect public understanding of participation in recycling schemes – but how does it do so and which approaches are most effective?

In Finland, present municipal waste management schemes make the transfer of responsibility over the non-wanted objects quite easy. Citizens are not even aware that, when discarding non-wanted objects, they give up ownership over them and that they are no longer responsible for them. Few question the morality of this, nor care for the fate of the discarded object. Embracing the ownership concept could, hypothetically, improve this view. If everyone were to became conscious of ownership and gain awareness of the responsibilities associated with ownership, then they would be more mindful in ceding their ownership. Consequently, they would become watchful in choosing a waste management option.

Introduction of separate waste recovery systems is a first step in raising awareness. The general public of Finland appears to favour recycling, but do not always effectively utilise it as a waste management option. What all must realise is that waste management is everyone's problem, and in society, each has a role to play. Hence public participation in recycling schemes is vital for their success. To cite an example, in Oulu, housing complexes are charged by the number of containers collected, so it is also in the interests of the housing association to recycle.

When the National Consumer Research Center of Finland surveyed consumer attitudes, intentions and actual participation in source separation and resource recovery of packaging waste (Heiskanen 1992), they found consumer attitudes towards recycling positive, but not always consistent. For example, 89% of the respondents thought that

consumers should always have more opportunities to sort waste for recycling. However, almost as many also considered that convenience was most important in waste management, yet 78% were willing to forgo convenience to reduce waste. This results in the question as to what extent would different factors encourage them to recycle. These factors are summarised in Table 24.

Table 24. To what extent do different factors encourage Finns to recycle (Heiskanen 1992).

Evidence that recycling saves natural resources	82%
Evidence of saving in the national economy	72%
Evidence of landfill space savings	66%
Free installation of new sorting bins in kitchen	65%
Return deposits	61%
Lower garbage fees	54%
If everyone else recycles	43%

The last condition in particular brings to mind Ajzen's theory. It is well-established that we perceive the influence of significant others who are close to us – such as family and friends - on our behaviour. However, the theory was tested and corroborated by Ajzen that there is also a perceived influence by 'unknown others' such as mass media on our perception of social norms and actual behaviour (Chan 1998). Kara Chan performed a study of recycling habits in Hong Kong, using Ajzen's planned behaviour model as a framework. The results show that the attitude of an individual was the most significant factor in predicting their actual behaviour. Thus, the best predictor of a person who will recycle is their attitude towards the idea of recycling (being 'green'). The second best predictor is the 'perceived behavioural control.' In other words, the perceived degree of difficulty in completing the behaviour, in this case separating recyclables and disposing of them in public receptacles. Third, the perceived level of 'subjective norm' felt from family, friends and neighbours as well as mass media. That is, how strongly will a behaviour, such as tossing aside recyclable tin cans, be punished by other social actors, or how strongly will proper recycling behaviour be rewarded by social actors, or indeed, by your own self-image and belief in being a good citizen. (Chan 1998) The conclusion reached by Chan is that mass media campaigns appealing to citizens of Hong Kong to recycle, are sound and have been shown to be effective in a sample group. Although not mentioned in her conclusions, Chan's results also suggest that mass media is not the most effective tool for changing behaviour. According to the results, the major factor in predicting behaviour is attitude. Per Ajzen's theory, mass media does not affect attitude, but rather social norms do. (Gray-Donald 2001)

While one could analyse the results of the Finnish survey at length, one might possibly wonder, was the wrong question posed? Perhaps one ought not to ask, "Why would you participate?", but rather "Why do you *not* participate?" Participating in waste recovery should not have a 'price;' it is everyone's responsibility. Evison and Read (2001) also observed that, while the environment remains a public concern, the general public appears much less concerned about household waste disposal than many other environmental issues. Inconvenience to the individual is continually cited as a major barrier towards recycling (Perrin & Barton 2001). Economic instruments may not necessarily have an

affect either. A case study conducted during a waste-removal strike in Canada concluded that, even when households were forced to bear the cost of disposal, waste sent to landfill was only slightly reduced (Salkie *et al.* 2001). It should be made clear to citizens that waste is simply an unwanted object, and they are at 'fault' for it resulting in waste. For instance, packaging waste is the concomitant of consumption. It is, therefore, reasonable to expect from citizens help in turning waste into something useful once more. Conversely, consumers' awareness of responsible ownership would promote opting for durable products as opposed to short-life, or single-use ones. One might also seek for opportunities to donate, or trade, still useful things and, above all, support waste recovery systems, which ensure that waste is utilised.

Another survey from the U.S.A. by the Harwood Group, examined patterns of consumption, and the consequences of those patterns for society and the environment. Their conclusion was that, beyond a general sense that development is on the "wrong track," public understanding of the links between consumption and the environment remained somewhat blurred. Despite the belief that personal values and lifestyle are deeply implicated in environmental problems, when asked about the environment, Americans tend to gravitate first to issues traditionally associated with environmentalism. The factors that are viewed as most significant - such as over-packaging, recycling, and waste - seem to be those that are most directly linked with the environment in the popular media. Broader, underlying trends, such as population and consumption, lag behind. Similarly, when people discuss how they could act to protect the environment, reducing consumption is not initially at the forefront of their minds. People believe recycling, antipollution laws, and reduced packaging would make more of a difference than reduced consumption. Most people seem to be waiting for someone else to act first: their neighbours, mega corporations, or the government. Of the Harwood survey respondents, 88% believe that protecting the environment will require "major changes in the way we live." Yet people resist examining their own lifestyles too closely, with only 51% agreeing that "my own buying habits have a negative effect on the environment." Despite their belief that lifestyles must change, many people are sceptical of each other's willingness to take action. Lacking a collective sense for moving forward together, people sit and wait for someone else to act first. (The Harwood Group 1995.)

User-pays schemes are raising awareness and encouraging householders to sort their waste when separate recyclables collection is available. However, the schemes are often abused. People put non-recyclables into the free collection bin to avoid paying for their removal. People may be tempted to dump waste in car parks and other public areas. The degree of abuse is a factor of the waste removal fee. In Germany, when the City of Munich increased waste disposal charges by 42% in 1993, and a few months later by another 8%, illegal dumping of waste increased alarmingly. In The Netherlands, eleven small towns have made use of the 'expensive rubbish bag' system. Only garbage that is put in a special rubbish bag was collected. These bags could be purchased in local stores. Some of the towns reported 60 % reduction in the amount of the garbage that had to be landfilled. It was noticed, however, that garbage traffic to neighbouring towns increased when the bags' price exceeded NLG 2,00 (0,91 EUROS). Neighbouring towns, therefore, that did not employ variable rate systems, were sometimes required to handle up to 20% more household waste. (Versteege 1994.) The reason for irresponsible waste dumping can be as basic as the lack of knowledge. Education and awareness-raising will continue to

underlie progress towards sustainable development by providing an essential tool to that end – knowledge (Read and Pongrácz 1999).

If people do not reach for the message, the message has to reach to them. It has been established that direct education for citizens has had a great effect on the success of waste recovery. A "Recycling Roadshow" in Inner London was aimed at knocking on the door of every household to inform residents of the recycling service. Eighteen months after the launch, 8% of all households had been contacted. As a result, the door-step recycling scheme rate improved from 9% in April 1995 to 11% in October 1996, and about 13% in December 1999, and the programme was still cost-effective. It was found that the main advantage of the face-to-face approach for the promotion of recycling services is that this type of contact is responsible for changing personal habits. This was due to the fact that the Roadshow team members are all well-versed in the benefits and issues of recycling within the Borough, and can thus provide the necessary, supportive evidence and arguments often required by unsure residents. Residents appeared more likely to change their behaviour after having spoken to a representative directly about the topic, and one who could answer their questions. This type of contact also provides the local authority with important feedback from the residents relating to collection problems that they experience, and the recycling team can then act immediately to remedy these problems, and improve the efficiency of the service provided. The results substantiate that there is no substitute for 'getting out from behind the desk' and talking to the residents, if one desires their participation in recycling schemes. (Read 1999b.)

The above case study could be viewed as a step towards a proof of the hypothesis that consumer awareness can be enhanced by educating consumers about their responsibilities as owners. Perhaps waste management officers should lead a 'waste crusade:' have face-to-face meetings with citizens, to educate them and thus increase awareness. As concluded by Thomas (2001) as well, additional research is needed to examine, compare and evaluate different communication strategies, with a focus on how they impact understanding and quality of participation.

The Sixth Environment Action Programme empowers citizens to change their behaviour towards waste, and suggests the initiation of actions to help citizens to benchmark and to improve their environmental performance, and improve the quality of information on the environment (Commission of the European Communities 2001).

5.4.2 Transfer of ownership

We may voluntarily cede our ownership over goods because the reasons that caused us to acquire them are no longer valid. The thing may not perform in accordance with its Purpose, while the loss of Performance may be due a to a fault in Structure or State. Moreover we might further argue that the thing does not have a Purpose for us in particular. We may sell the unwanted things, if there is buyer for them. The basic theory of properties suggests that transferring ownership by economic transaction only happens when the costs of the transaction are less than the gained profit. While many waste items could find new owners that can assign a new Purpose, the primary owners do not, generally, make the effort to locate a secondary owner, nor sell their single items, if it

does not entail an attractive return. If we cannot find a buyer for our unwanted things with expenditures less than the expected benefit, we may simply abandon our property. In the case when the mass of items accumulated in a community (municipality or region) represents significant worth, the community, or an individual organisation, may decide to collect the waste items and sell them to another party. Old newspaper is a waste for us, but in Finland, when we place it into a waste paper collection bin, the mass of collected newsprint will assume a new owner: the collector, who may then sell it to a paper mill.

Waste definitions depict the fatal moment when a once-useful thing turns into waste. In some cases, the thing is only temporarily useless. When there is a second Purpose available for the thing, after having fulfilled the first one, it is a waste only during the interval before being assigned its new Purpose. Re-use or closed-loop recycling are such cases. In Finland, when buying soft drinks, or beer, either in a glass bottle or an aluminium can, the empty container remains waste in the hands of the consumer until he returns it to the retailer for refund. Bottles are refilled, or recycled if broken, and aluminium cans are recycled into new cans.

In the absence of secondary material utilisation-options described above, the inhabitants or housing companies pay the organisation responsible for waste collection and for their service of waste removal. Many are unaware that, in this way, they transferred ownership over and responsibility for the unwanted things. The aggregate object of the municipal solid waste often ends up in landfill sites. From the point of ownership, landfill is an interesting issue. Basically, from the moment we placed our waste into mixed collection bins, we know their destiny: landfill. The question is, do landfill operators become the new owners of these waste items? Since the primary owners did not want to be responsible for the waste items anymore, this responsibility is taken over by the landfill operators. By placing waste into assigned bins, eventually we are transferring our ownership to the landfill operator through the collector. Similarly, when litter is picked up by a clean-up team, one may say that they are assuming ownership by occupying res nullius and later transfer this ownership to the landfill operator. Controlled disposal of abandoned things is a service, with a goal of preventing adverse health or environmental impacts, or simply to avoid æsthetical unsightliness. The landfill operator also has the right to manipulate the waste. Therefore, by definition, it became the owner of the aggregate object. Since these waste items have assumed a new owner, would this mean that they become non-wastes? The Purpose of the landfill is simply to take over the responsibility from the primary owners over their non-wanted things, it does not necessarily give a Purpose to the waste. Theoretically, it is possible to assign Purpose also to the waste in the landfill, for example, when landfill gas is collected with the aim of utilisation. As well, with the use of an aerobic landfill technology described in §2.2.7, one achieves a state when organic matter in the landfill is composted. Finally, landfill can be viewed as a temporary storage, with the hope of landfill mining in the future for recovery of useful components, and ultimately giving Purpose to them.

5.5 The ownership concept in legislation

The ownership concept in legislation might bring to mind copyrights and ownership of intellectual property. Generally, authors fiercely defend their right over their intellectual creations: patents, artistic or literary works, logos/trademarks, *etc.* Producers of material goods also protect their creations. If this creation, however, is a liability, waste or even a dangerous compound, then legislation is needed to remind the creators of their ownership responsibilities rather than just protecting their ownership rights. There is a danger that the producer may not even be aware of being an owner of a dangerous compound. For example, for centuries humans were unaware of the existence of compounds such as dioxins. Every producer should, however, be aware of the impending risk.

Depending on the nature of a waste, owners may be restricted in their right of freely giving up the ownership. For instance, when we pay for the service of waste removal in the form of fees, direct or indirect taxes, this can be viewed as a form of legal restriction in our right to abandon ownership. It is important to evaluate the risk if one is allowed to claim ownership over a thing, and accordingly, if one is allowed to surrender ownership. The role of legislation is to decide, evaluate and monitor the conditions under which owners can give up their ownership. This, naturally, includes evaluation of the hazard of a waste, and prescribing, or motivating actions owners should take, if intending to give up their ownership. (Pongrácz & Pohjola 1998.) There are other, non-waste related cases as well, such as when a property becomes a liability, consequently the owners would cede ownership. Scafidi *et al.* (1998) describe a "wealth-maximising landlord" who, when required to pay delinquent taxes would rather cede ownership of his residential property when the value of all outstanding liens exceeds the property's market value. At the other extreme, Pritchard (1995) observed that higher old car taxes reduce registrations because low-income owners cannot buy older or cheaper cars, and thereby abandon ownership.

In 1856, long before expressions like 'air pollution' and 'hazardous waste' were coined, a barrister named Comstock argued in the case Wyneham *versus* People (quoted in Hohfeld 1919):

"I can form no notion of property which does not include the essential characteristics and attributes with which it is clothed by the laws of society... among which are, fundamentally the right of the occupant or owner to use and enjoy (the objects) exclusively, and his absolute power to sell and dispose of them."

Present day environmental regulators would disagree with Comstock. Even Hohfeld later argued that power correlates with liability. The law *can* impose restrictions upon what persons may do with their property. The general rule is: "any use was allowed that did not interfere with other people's property." This general restriction from the common law of property corresponds to the economic concept of external cost. For instance, a factory discharging waste effluent into a river is generating an externality to the next factory downriver. These forms of interferences, called "public bads" (since they act like public goods, except that they are 'bad' rather than 'good'), cannot be solved by private bargaining solutions, consequently, they are not self-correcting. Some form of public policy remedy is called for, or regulation by an administrative agency. (Cooter & Ulen 1996.) Water and air pollution emissions, jointly referred to as effluent taxes, waste or

landfill taxes, regulations on hazardous waste disposal are examples of legal restrictions to abandoning ownership.

It was previously argued that, when the mass of items accumulated in a community represents significant worth, the community or individual organisation may decide to separately collect and sell them. This decision may also emerge when the community decides that the potential hazard of a material dissipating in a landfill may pose a significant risk to human health or the environment. For example, in 1998, the Swedish battery ordinance came into effect, which states that all kinds of household batteries must be collected to avoid the spread of cadmium, mercury and lead (Rydh & Karlstöm 2002).

Even if materials do not constitute a hazard comparable to that of batteries, the sheer volume of them may trigger restrictive measures. If the communities do not make the decision to divert large-volume waste fractions entering landfill, legislation has to interfere and force them to do so. The largest waste fractions in municipal solid waste, and as a result contained in municipal landfill sites, are biodegradable materials – food and yard wastes and paper. To alleviate the situation, the Landfill Directive (European Council 1999) was imposed, prescribing 35% reduction of these materials entering landfills by 2016.

The argument in this Chapter of this work is that a thing shall be recognised as waste if its owner wishes to cede ownership of the thing, and there is no new owner assigned to it nor a newly assigned Purpose. In this case, the proper waste management authority will assume ownership and take responsibility for the thing, or enforce the previous owner to perform his – let one say – last act of responsibility in order to avoid the risk to human health or the environment, which is the principal role of waste management. To refer to Einstein's observation, the problems waste has caused this far, will not likely be solved by continuing the *status quo*, of waste management: the roles of waste management should be reconsidered. How the new definitions and the ownership concept call for the definition, or re-definition of the roles of waste management will be discussed in Chapter 6.

6 Defining the roles of waste management

"An ounce of prevention is worth a pound of cure." - Benjamin Franklin

It is far too often possible to see such points-of-view that waste is the final destination, and waste management is the last step of material flow. That is one crucially important part of it. Different waste segments, as presented in Chapter 2, pose different challenges for waste management. In the case of MSW, WEEE, end-of-life vehicles, or demolition waste, the real issue is about things that have previously served their purpose and have been disposed of by their owners when turned to waste. In the case of industrial waste, mining waste, electricity-generation waste and, occasionally, agricultural waste, the waste thing is a by-product of some economic activity, thus it is a newly emerging thing: being waste is actually the *first step* of its life.

For most of these activities, waste management requirements are heavily regulated. In some cases the main management goal is utilisation, disassembling, or safe disposal. In other cases, the main goal is avoidance, substitution or minimisation. All require rather different reactions, some have to be planned for the existing waste, some before the waste is even produced. Subsequently, waste management is not only the art of how to treat waste and it is neither only a service of waste removal. The main argument is: the manner in which the waste is described prescribes the way it is going to be acted upon. Instead of looking at waste-by-waste types defined by origin, let us define activity upon waste based on the new waste taxonomy proposed in this thesis (see Table 21, §4.7).

6.1 Activity upon waste

Classifying waste based on the reason it became waste implicitly offers a solution how could it be turned into non-waste. The pursuant waste management activities were suggested by the taxonomy of wastes (Pongrácz & Pohjola 1997):

Waste is a non-wanted, not avoided output with no Purpose.

In this instance, waste is process-specific and can be avoided or minimised by changing the process Performance. Most industrial processes that are aiming at a necessary and desirable output leave behind undesired by-products that are called waste. Here, waste management would refer to how to design, retrofit and operate the process, with the aim of minimising the overall wasting of material and energy. This problem also calls for extending the designer's responsibility to the 'non-useful' by-product's fate. A viable solution could be looking for waste-trade possibilities: the waste of one process may be a valuable raw material for another.

Waste is a product that has fulfilled its single intended Purpose.

The best examples for this category are packaging. Waste management in this situation would mean the assumption of the responsibility of the product's fate after it has fulfilled its Purpose at the design phase. The domain procedural knowledge includes the following: If the most probable fate is to end up in landfill, opt for lightweight, low volume or collapsible shape, flexible walls. If heading to material recovery, use materials that are the most economical to recycle. If incineration is planned, omit ingredients that may lead to toxic emissions, *etc*.

Waste is a product with unsatisfactory Performance.

Most products have a certain life span. After that time they cease to be useful. Waste management refers to a product's design stage and is associated with how to create goods with optimum lifetime, the use of ecological design, and how to design for assembly and disassembly. Even if the whole product ceased to be useful, some parts of it can still be utilised, *etc.* Material recycling and energy recovery activities also fall into this category.

Waste is a thing that its owner failed to use it for its Purpose

This problem raises ethical issues, which have been touched upon before. While there is a possibility of controlling consumers by legislation, or by the use of motivation, the best way of influencing people is by raising awareness. Increasing their knowledge through education, consumers become more conscious of their actions and learn their responsibilities, and possibilities, in environmental protection. No regulation can be as effective as a well-informed, environmentally-conscious, ethical public.

6.2 Turning waste to non-waste

The first three of the four waste classes (see Table 21) are wastes having a fault in their Purpose attribute. An obvious solution to turn the waste into non-waste is assigning new Purpose to the waste object. Only waste of Class 4 may be readily used by a new owner. The new owner can continue to use the object for its original Purpose, if it is retrievable. If it cannot be retrieved from the collective waste object, it will be just part of the purposeless waste mass. Naturally, it is difficult to identify and assign Purpose to a

collective object. The structure of the collective object has to be disaggregated so that new Purpose can be assigned to the structural units. The act of waste management, on the other hand, would be to change the Structure, or modify the State of some, or all structural parts, to achieve the expected Performance. Re-use, recycling, disintegration and incineration all fall into this activity class. The basic, waste-related activities are Purpose readjustment without Structure manipulation to make Performance satisfactory, or readjustment of Structure by accepting current Purpose.

The higher level (or meta-level) activities that are set by legislation, constrain the right to give up ownership, or impose duties to modify the Purpose and/or Structure or State. Indeed, legislation, or authorities, should intervene when one resumes ownership over a thing and there is no new owner for it. Based on these considerations, the role of waste management can be argued to be as follows (Pongrácz & Pohjola 1999b):

The role of waste management is to turn waste into non-waste by finding a new owner and/or giving a new Purpose to the waste.

An interesting question that arises is, can every waste be turned into non-waste? Theoretically, yes. Waste defined as in Definition 1, can theoretically be turned into a non-waste as defined in Definition 4, by simply assigning a new owner or a new Purpose to it. It does not mean that it is practicably possible, or even that we should always strive towards it when possible. This is to say that it should be of highest priority to waste management, or a major goal, to turn wastes into non-wastes; however, this is not always possible: we cannot upgrade every waste into a higher value thing.

According to Dijkema *et al.* (2000), "a substance or object is qualified as waste, when it is not used to its full potential." Under this paradigm, any production process can be used for the transformation of waste. In networks of industrial plants, the waste of one plant can be the feedstock of another. Normally, in a transaction that concerns byproducts, neither of the two parties involved considers the substance flow a waste. If, however, the receiving party terminates its activity, the producer would immediately experience problems in disposing of its by-products, and the substance would then be qualified as a waste product. "Waste, therefore, is an emerged quality of a substance or object," conclude Dijkema *et al.* Subsequent processing of any waste material causes the emerged quality to submerge again.

Suppose that waste is unable to be turned into non-waste. Are there then ultimate wastes? The argument is that there is no such thing as 'ultimate waste.' If we dispose of waste in landfills, it cannot be said that it is doomed to be an ultimate waste because it cannot be foreseen what will happen to it in the future. "Landfill mining" may be a viable method of obtaining raw materials at some future date – inorganic waste can be recovered and recycled. The lifecycle of the artefact may also end with (re-)transformation into a natural thing. When an organic waste is completely decomposed and its properties can no longer be recognised as being an artefact, it is a natural thing.

The Community strategy for waste management insists on the need for promoting waste recovery with a view to reducing the quantity of waste for disposal (European Council 1997). The ultimate goal of waste management is said to be (Riemer & Kristoffersen 1999): "To keep as much waste as possible away from final disposal." The Sixth Environmental Action Programme lays down targets for reduction of waste going to

final disposal by 20% by 2010, compared to 2000, and in the order of 50% by 2050 (Commission of the European Communities 2001). Many of the final disposal options can be viewed as expecting 'Nature' to take care of the waste. Such disposal methods include:

- land treatment (i.e. biodegradation of liquid or sludgy discards in soils),
- deep injection of pumpable discards into wells, salt domes or naturally occurring repositories,
- surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.),
- release into a water body including sea-bed insertion.

These methods arguably turn waste into natural things. Engineered landfill, however, is different from these final disposal options because in the short-term, landfill does not turn waste into natural thing, neither does it turn wastes into non-wastes. The purpose of the landfill can be argued to be to remove the waste – human interface. However, waste *is* retrievable from landfills. Large percentages of waste in landfills is inert, towards which legislation is striving (*e.g.* the EU Landfill Directive). One possible approach to viewing landfill as part of waste management is to oversee the resources until possible utilisation at a later time.

6.3 Re-defining waste management

In its Article 1, the Council Directive on Waste, defined waste management as (European Council 1991a):

"Waste management shall mean collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites."

This definition of waste management has the same organisational approach as the definition of waste. It is concerned about the existing amount of waste, trying to minimise the human-waste or environment-waste interface, to minimise potential impact. It must be noted, again, that this approach is very useful and important. It does not go into the depth of the concept, does not try to explain or clarify the concept, but that is not its role either. Self-confessedly, the role is to protect human health and the environment. In this context, 'the environment' is to mean the whole of the natural world inhabited by living organisms, considered vulnerable to pollution. Cheyne and Purdue (1995) argue that waste management is concerned not only with final disposal of waste but with the whole cycle of waste creation, transport, storage, treatment and recovery, and does so in order toprevent pollution and harm from pollution taking place. Waste management strategies, therefore, should include a wide range of policies, such as assignment of liability, duty of care, controls over collection, transport and disposal and, not the last, reduction and/or elimination of waste.

On the other hand, the *waste management hierarchy* (Fig. 14), which is a widely accepted list of preferred waste management options, gives priority to waste minimisation, which includes changing processes to prevent waste.

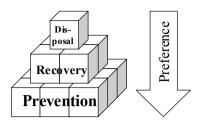


Fig. 14. The waste management hierarchy, as a pyramid of preference.

The waste management pyramid intends to illustrate that ideally, one shall build up the waste management strategy primarily using prevention measures; and secondarily, relying on recovery, and disposal methods shall be used sparingly. The European Topic Centre on Waste (ETC/W) of the European Environmental Agency (1999) defined waste minimisation measures to include waste prevention, internal recycling of production waste, source-oriented improvement of waste quality, and re-use of products for the same purpose. Other waste management measures include external recycling, sorting of waste, re-use for another purpose and energy recovery (European Topic Centre on Waste 1999). Waste regulation at virtually every level gives priority to prevention; however, the definition of waste management suggests that its role to be merely to get rid of existing waste. The Guideline for LIFE-environment demonstration projects (European Council 2000a) also places emphasis on prevention and encourages waste management research toward prevention, re-use, recovery and recycling of waste.

Semantically, the expression is an interesting use of words. 'To manage' is, according to the *Merriam-Webster's Dictionary Online*: "to handle or direct with a degree of skill; to work upon or try to alter for a purpose; to succeed in accomplishing or to direct or carry on business or affairs." While 'management' is defined as: "judicious use of means to achieve an end." It appears from these definitions, and it is also our understanding of management as presented in an earlier paper (Pongrácz & Pohjola 1998), that management is control of activities, while the expression of 'waste management' semantically suggests that it is control of materials.

Another question raised is, if the aim of management is to achieve an end, what would be that end, and what then is the aim of waste management? The purpose of waste management is protection of the environment, human health and natural resources. Waste management shall be understood as a system, providing medium for making changes in the way people behave with respect to waste. (Pongrácz & Pohjola 1999a.) It has been concluded that waste management can be understood as:

Definition 5 Waste management is control of waste-related activities with the aim of protecting human health and the environment and resources conservation.

Waste-related activities include waste-creating processes, waste handling as well as waste utilisation. Control of these activities occurs based on the considerations prescribed earlier: Purpose readjustment; Structure and State manipulation. It is important that the main objective of waste management is, besides waste avoidance, turning wastes into

non-wastes and preventing waste from final disposal, especially of such disposal which does not utilise waste by any means. This proposed definition is in line with the European Council Resolution on waste policy, which states (European Council 1990):

"In the interest of environmental protection, there is a need for a comprehensive waste policy in the Community, which deals with all waste, regardless of whether it is to be recycled, re-used or disposed of."

6.4 The role of legislation in waste management

As stated earlier, legislation is to monitor waste management activities, prescribing conditions by its regulations to avoid contamination of the environment. Legislation can thus be considered as a meta-level activity, which monitors the base level activity and sets targets for activities upon waste. From the object-oriented view, this happens by communication between the objects. Activity upon a target disaggregates into two sub-activities: the management activity communicating mainly with a meta-level description or prescription of the target; and the activity manipulating the target and/or its model directly – in this context, management is used in its meaning as "control of activities for a purpose." On the most generic level, an activity upon a target can be modelled as a couplet of objects communicating with each other as represented in Fig. 15.

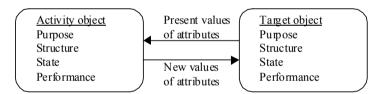


Fig. 15. Object-oriented representation of an activity upon a target (Pohjola & Tanskanen 1998).

The activity object monitors the current values of the four attributes of the target object and is capable of sending messages to update these. In Fig. 16, the management activity monitors the current State of the target through the model of the target. It builds up an impression of the State of the target object and sets new sub-goals for the manipulating activity. The target is a waste-related process or product. The three objects communicating cyclically can be viewed as a generic model of waste management (Pongrácz & Pohjola 1998). Waste manipulation is here understood in accordance with the definition of waste management: control of waste-related activities with the aim of protecting the environment and resources conservation. In this triplet of objects, also referred to as a design cycle (Pohjola and Tanskanen 1998), the management level activity refers to the role of legislation. Legislation sets goals for waste management, *e.g.* by fixing recycling rates to be achieved, setting targets to reduce emissions, prescribing the goal of stabilising waste production at a given level, or banning the export of certain categories of waste, *etc.* Part of these regulations and/or objectives and their effort to monitor activity upon waste to avoid contamination of the environment are necessary.

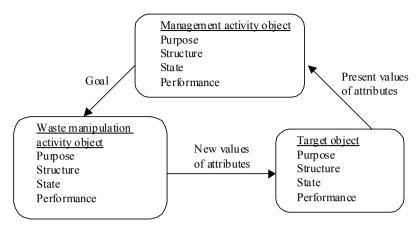


Fig. 16. Object-oriented representation of generic waste management cycle (Pongrácz & Pohjola 1998).

However, the international regulation of recycling by fixed rates may be economically and environmentally detrimental. For the aim of resource conservation, instead of fixed quotas of recovery or recycling percentages, one is concerned with the question of how could the amount of things belonging to the individual waste classes be minimised, or how could wastes be turned to non-wastes.

6.5 Toward waste prevention

As an activity upon waste (as discussed in §6.1), the approach to waste minimisation will be also presented within the four classes of waste.

6.5.1 Prevent creating things with no Purpose

When assignation of a new Purpose is not possible, the aim is then to reduce the amount of waste that is produced with no Purpose. Enhancement of the environmental performance of the production process shall aim at reducing emissions and/or substituting potentially dangerous compounds to reduce the toxicity of waste. Design for the Environment (DFE), in particular Design for Safety is required. Aiming at a process that involves minimal waste production, three options have to be considered. Firstly, reducing the use of natural resources since mining is a major solid waste producer. Closed- as well as open-loop recycling can contribute to this end. Secondly, reduction of energy use, given that generating energy involves waste-creating that can be allocated to the product. Thirdly, reduce water consumption as wastewater treatment involves sludge production. A paper on the effectiveness of waste minimisation clubs in reducing the demand for water revealed that companies were able to reduce water consumption by approximately

30% (Holt *et al.* 2000). Enhancing the logistics of the production process can also greatly contribute to a more efficient production, which in turn contributes to waste reduction.

6.5.2 Prevent creating things with a single finite Purpose

Reduction of waste in this class requires product design enhancement and extending designer responsibility. The future Purpose of the product when it becomes waste can be planned using DFE methods, for example, Design for Materials Recyclability, Design for Incineration, or Design for Disposal. In the case of packaging, especially that of plastics, feedstock recycling is an ideal utilisation of difficult-to-recycle plastics, since energy recovery also contributes to waste minimisation by avoiding usage of fossil fuels, as their acquisition also involves waste creation. In the case of refillable packaging, some economic instruments can also help reduce waste. Monetary deposits, for example, will motivate consumers to return the waste package.

6.5.3 Prevent creating things that cease performing

Increased functionality of products can postpone its transformation to waste. If the loss of Performance is only due to a faulty part, changing that part is an option. To that end, Design for Refurbishment is recommended. When refurbishment is not viable, recovery of the useful constituent parts is preferred. Design for Disassembly can help achieve this. There is also a need for legal instruments, *i.e.*, product take-back responsibilities so that the consumer has a possibility to return a non-functional product (electronic appliances, cars, *etc.*) to the manufacturer. Another option is leasing the product instead of selling to the consumer, a practice widespread in the use of copier machines, and introduced to cars as well. Use of economic instruments, such as deposits is, again, also recommended.

6.5.4 Preventing owners from failing use things for their Purpose

Enhancing the environmental performance and/or functionality may make the product more desirable to the owner, or may make it easier to find a new owner. Hence the owner would be less prone to give up ownership of the product. Use of legal instruments, such as increasing owner responsibility can prevent uncontrolled abandonment of ownership. In summary, waste minimisation requires innovative process design and product design as well as the use of economic and legal instruments. They are listed in Table 25.

Table 25. Instruments for waste minimisation.

Process design enhancements	Increase process efficiency,
	Substitution of dangerous compounds,
	Design for Process Safety,
	Minimisation of the use of 'virgin' materials,
	Minimisation of energy use,
	Minimisation of water use.
Product design changes	Increase functionality of the product,
	Increase the environmental performance of the product,
	DFE: Design for Refurbishment/ Disassembly/ Material Recycling/
	Incineration/ Disposal, etc.
Economic and legal instrument	Deposit/refund systems,
_	Product take-back responsibility,
	Increased owner responsibility.

6.6 Breaking down the pyramid

The waste management hierarchy is a useful guideline, but it ought not to be used as a strict set of rules. The range of instruments that can lead to waste reduction is much greater than it appears. We shall break down the traditional hierarchy pyramid (Fig. 17) and, instead, allow a free choice of waste management options to build up a waste management strategy that best serves the goals of waste management: protection of the environment and human health, and conservation of resources.

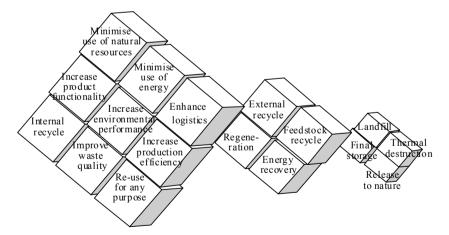


Fig. 17. Breaking down the hierarchy pyramid.

6.7 Integrated resources management

Minimising the amount of waste an organisation or an individual produces goes hand-inhand with optimising their use of resources. Indeed, waste management is often extended to integrated resources management, in order to avoid the negative image associated with wastes. The R'99 Conference on Recovery, Recycling and Re-integration defined Integrated Resources Management as:

"Integrated Resources Management is the recovery of economic value from any resource produced naturally or by society while considering ecological, economic, technological and social implications of recovery, recycling and re-integration technologies."

If the broader term of *resource optimisation* is applied instead of waste minimisation, then another failing in the thinking associated with waste minimisation strategies would be addressed: that of the definition of waste itself.

How an economically affordable, environmentally effective and socially acceptable Municipal Solid Waste Management System can be developed is currently unclear. Considerable research has been done on the practical aspects of municipal waste management (*i.e.* transport, treatment and disposal) and how people feel about source separation, recycling, incineration, and landfill; however, the perspective of the waste manager within the context of long-term planning is often ignored. In a study by Wilson *et al.* (2001), waste managers from eleven different, cutting-edge European municipal solid waste programmes in nine different countries were interviewed. None of the programmes Wilson studied became 'Integrated Waste Management (IWM) systems' instantly. Rather, the process was one of continual evolution and system optimisation. This is demonstrated schematically in Fig. 18.

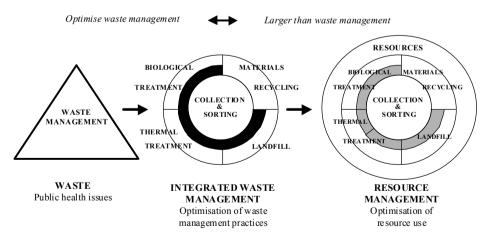


Fig. 18. Sample evolution for IWM programme developments (Wilson et al. 2001).

The evolutionary trend observed begun with waste management primarily addressing the issue of public health and safety. Through an organised system of waste management optimisation, this initial approach is superseded by an integrated approach to waste

management where economic, social and environmental concerns are added to the system. Eventually, an integrated waste management system can itself become part of an urban resource management system, where all resources such as water, energy, CO₂ balance, and waste are managed within a single optimised system. (Wilson *et al.* 2001.)

Industrial waste management requires introducing waste minimisation within industry. For economic as well as environmental reasons, it is in the waste generator's interest to minimise waste. Waste-generating industries need to think processes over from start to end, and to engage in new dimensions of research and development. In the case of manufactured products, waste minimisation and resource maximisation can most easily be addressed at the design stage. According to the European Chemical Industry Federation (CEFIC) the industry is aware of this challenge, thus European industry still has the opportunity to shape the future path waste management will take. (Euroenviron 1993.)

In summation, there are few instant solutions to reducing waste, but taking an expanded view of what constitutes waste, and examining actions as designers, producers or consumers, will help make the best use of available resources. Waste management should grow into integrated resources management, where a wide range of instruments (Fig. 19) supports an effective flow of materials within society.

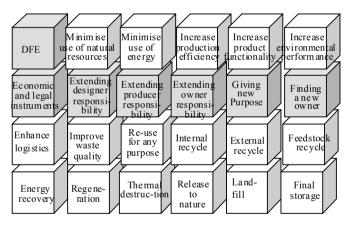


Fig. 19. Elements of Integrated Waste Management.

6.8 Industrial Ecology and Waste Management

Industrial Ecology (IE) is an approach to industry-environment interactions to aid in evaluating and minimising impacts. IE, as applied in manufacturing, involves the design of industrial processes and products from the dual perspectives of product competitiveness and environmental interactions. This systems-oriented vision accepts the premise that industrial design and manufacturing processes are not performed in isolation from their surroundings, but rather are influenced by them and, in turn, have influence on them. IE seeks to optimise resource use, energy and capital from virgin material, to

finished material, to component, to product, to obsolete product, to disposal and, eventually, re-integration into the material cycle. One of the most important concepts of IE is that, like the biological system, it rejects the concept of waste. In Nature, nothing is eternally discarded; in various ways, all materials are re-used, generally with great efficiency. Similarly, in the industrial world it should be realised that wastes are merely residues that the economy has not yet learned to use efficiently. (Graedel & Allenby 1995.)

One of the goals of an IE system, at the industry level, is that every material that enters the process will leave the process as a marketable product. This can be expressed also in the manner that there will not be a product without a Purpose leaving the process and not one that will be without an owner. As well, in an Industrial Ecology loop, every product is designed so that it can be used to create useful products after the end of its lifecycle. This would mean that after the product has fulfilled its Purpose, or does not perform in accordance with its Purpose, it would be assigned another Purpose. The new, object-oriented waste concepts and definitions thus accurately illustrate the goals of Industrial Ecology (Fig. 20). Engineers should keep in mind that, in a sustainable process, no object should be created without a specified Purpose, that there always should be a second Purpose to assign after the first one is fulfilled, and that every product has to be produced for an owner. (Pongrácz 1999.)

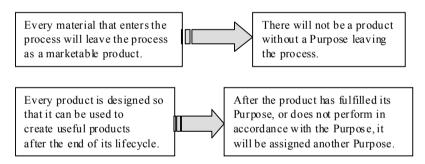


Fig. 20. Translating the goals of Industrial Ecology.

Industrial Ecology is a paradigm that could possibly lead toward sustainability. It could be suggested that waste management should be connected with the paradigm of IE. There is a need for an infrastructure to enable individuals, private firms, and other entities to continue their progress in adopting practices and methodologies based on Industrial Ecology approaches. These are (Allenby 1999):

- 1. Establishing general regulatory policies (boundary conditions) designed to encourage appropriate behaviour on the part of producers and consumers.
- 2. Establishing means to define and prioritise environmental risks, both among themselves and in conjunction with other risks and costs raised by policy decisions.
- 3. Defining and prioritising what values that private firms and individual can use to make trade-offs in their operations.
- 4. Supporting research and development and providing Industrial Ecology tools, which because of their broad applicability and the inability of any private producer to capture the full benefits of the activity, are public goods.

These four points after Allenby (1999) are applicable to waste management as well. Notwithstanding the above, the author of this thesis feels that there is a need to supplement them. Therefore, the next six points should be appended to the concept.

- 5. Enhance present waste regulation to encourage appropriate waste management practices. Legislation should interfere when there is no new owner available for the discarded things. Legislation is to oversee that waste management fulfils its goal of resources conservation and environmental protection.
- 6. The purpose of an integrated material policy should be to ensure safe handling of all materials regardless of where they are in their life cycle, and to regulate every material equally, regardless of whether it is virgin or originates in a residual stream, according to the actual risks involved.
- 7. While recycling has an important role, it should not be regulated by fixed rates, and there is a need of rethinking priorities, and target groups. Recycling is to be further encouraged, but more freedom shall be given to local authorities to choose a waste management option.
- 8. Priority shall be given to waste minimisation in industry, to this end support shall be given to research and development to establish scientific guidance. However, while a waste management hierarchy is a useful guide, it shall not be used as a strict set of rules
- 9. The main goal of waste management is turning wastes to non-wastes. To this end, there is a need to involve the public, and to educate them about their responsibility as owners
- 10. Finally, there is a great need to enhance the communication in waste management, between the actors of waste management as well as its planners and legislators, in order to support sustainable waste management.

There is a recognisable trend towards dematerialization of society, towards which Industrial Ecology points at. It can be monitored in the switch from the use of traditional, long-lasting materials such as metals and wood to the plastic-oriented, disposable consumer society of today, and a trend towards an information society of the future, where information and intellectual capital increasingly displace material- and energy-intensive technologies. While this scheme remains speculative at this point, it is important to recognise that materials use and selection and concomitant environmental impacts are a profoundly cultural phenomenon. (Allenby 1999.)

7 Toward the Theory of Waste Management

"There is never going to be a Theory of Waste Management by Pongrácz as there is a Theory of Relativity by Einstein." - Undisclosed

It has been the observation that some find the idea of a 'Waste Management Theory' disturbing and are dubious about its justification. Why would a theory of waste management be required? Waste management is a practical discipline, seeking solutions to specific waste problems. Given that the everyday problems of waste management are so important to solve, it may even appear that theorising, instead of acting, is a waste of time or effort. Campbell (1957) explains that the desire to rely on "practical conclusions" rather than on the reasoning of the 'theorist' is founded merely on ignorance. He strongly argues that concepts, such as something that is only 'true in theory,' have their foundation in incompetence. Campbell admits that, if a conclusion can be obtained by a brief and simple line of reasoning, then complicated argumentation is to be avoided, as it is more likely to lead to error. On the other hand, the views of "practical men" are usually derived from assumptions and arguments no less complex than those on which theory is based. However, if they are less openly expressed, they are more liable to error.

What then is the justification for a Theory of Waste Management? As it has been previously illustrated, waste is a human-related concept. There is no such thing as 'absolute waste:' a thing that would be waste under every condition, at every time, and for everyone or everything. Precisely due to the fact that waste *is* a concept, calls for it to be analysed conceptually. Human beings have the cognitive ability to disregard unimportant or accidental characteristics, properties and relationships, and to emphasise the significant and important ones, in order to focus on the generic features of the perceived/observed piece of reality. Abstract conceptualisation, as a cognitive process, has helped humans to obtain knowledge in all areas; to group and classify it, and to provide it with suitable structure. Creating and expanding individual sciences and meta-sciences have resulted (Hubka & Eder 1988). Candidly, one might say that the reason why a Theory of Waste Management ought to be formulated is because we have the cognitive ability to do so.

The uppermost human achievement is 'creating something new' that is of some potential benefit to mankind. That 'something new' includes artistic work, processes and products, or knowledge. Scientific knowledge can be useful, but the main purpose of

scientific activity tends to be to generate knowledge, not to concern itself with its usefulness. (Eder 1995.) As Louis Pasteur once stated to a group of medical students:

"Without theory, practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention. It is you especially who are obliged not to share the opinion of those narrow minds who reject everything in science which has no immediate application."

Constructing the Theory of Waste Management is an effort towards scientification of waste management. In order to effect such scientification and to evolve any theory in waste management, an effective tool is needed that can be applied in an encompassing schematic view. The author of this work thus decided to choose the PSSP modelling language to express these views because the PSSP is generic and non-domain specific. The contribution of this work, to evolving the Theory of Waste Management, is a conceptual description of waste management, providing definitions of all waste-related concepts, and suggesting a methodology of waste management. A domain-specific set of problems is put forward and described, with their relationship explained, thus providing a system of logically interconnected knowledge sets. Hence the application of the PSSP to the evolution of the Theory of Waste Management is incidental in an effort to organise the diverse variables of the waste management system as it stands today.

7.1 The practical role of theories

Theory, as a concept, appears to be one of those 'obvious' things that everyone seems to understand the meaning of and does not require explanation. To illustrate, take the Theory of Relativity. One would be rather worried about explaining the concept of relativity, and not that of the scientific concept of theory. In addition, there is a clear distinction drawn between using the word 'theory' in the scientific domain, as opposed to everyday life. In common usage, 'theory' is contrasted with 'practice.' The word 'theory' is associated with a feeling of uncertainty. Propositions are apt to be termed theories, because their truth is not certain. In the philosophical sense, the relationship between theory and practice is rather different. The word 'theory' originally means to observe, or to contemplate. As Campbell (1957) explains: "Theory, in its origin, is the state of contemplation as distinct from the state of action." Niiniluoto (1980) argues that the goals of scientific conception and theory formation are theoretical as well as practical. With the help of scientific research, we try to explain and comprehend the facts and regularities of nature, humans, and their society. The former goal helps us to orientate and successfully act in nature and human society, eventually control and change it; the latter goal satisfies our intellectual curiosity, our need to search for truth, and understand the world around

It is fashionable to speak of modern, Western culture as existing in the science and technology era. While there exists some rivalry between these two, they meet in scientific research at one end, and in engineering design at the other end. Scientific research results in scientific laws and theories, while the implications of engineering design are buildings, machines, systems, *etc.*, intended to function according to the objectives they were

designed for. (Eekels 2001b.) Niiniluoto (1980) argues that present scientific development has progressed in such a way that the number of technical applications of science have increased, while the theories themselves are becoming more and more abstract, reaching beyond everyday experiences. Most who have written – and write – about theories and cognitive reasoning, are from the fields of empirical sciences, or the philosophy of science. However, new scientific specialities may emerge from previously practical fields – witness the Middle Ages, whence the techniques that separated the master from the amateur in the handicraft arts became the most closely guarded secrets of the guild.

According to Niiniluoto (1995), the scientification of human arts and technologies follows a general pattern: An activity requiring specific skills becomes a craft or profession. The skill is transmitted from masters to novices, but there will also be an attempt to formulate its content and rules of thumb, and to collect them into practical guidebooks. Such collections of rules may be based upon everyday experience or pseudoscientific, 'magical' and religious doctrines. A new science is born, when the effectiveness of such rules is tested by scientific methods and explained by scientific theories. A practical discipline of this sort may be called *Design Science*.

7.2 Design Science

Design Science is an attempt to provide a general, comprehensive theory of designing (Hubka & Eder 1988). Designing is considered to be one of the significant intellectual activities because of its complexity and the effects its results have on society (Gero & McNeill 1998). The emergence of Design Science is an important model of speciality formations. Herbert Simon's famous "The Sciences of the Artificial" suggests that all practitioners, because they produce artefacts of one kind or another, are designers. As he argues: "The proper study of mankind is the science of design, not only as the professional component of a technical education but as a core discipline for every liberally educated man" (Simon 1979). Simon suggested that the artificial world is centred on an interface between the inner and outer environments; it is concerned with attaining goals by adapting the former to the latter. As a working definition of why design arises, this is an intriguing suggestion. It proposes culture as the mediator between the natural world and the world of ideas (Stairs 1997).

In the field of design thinking, there exist many different points of view about design process (Dorst & Dijkhuis 1995). Among them, the theory derived from human problemsolving (Newell & Simon 1972) maintains that human thinking is a symbolic process through the problem space, which consists of several series of alternative searches from the initial state to the goal state (Simon 1979). This theory has become one of the most important ones in cognitive psychology, artificial intelligence, and computer-aided design (Liu 1996). According to Ohtawara *et al.* (2002), a design problem can be viewed as to seeking the mapping between the functional requirements and the design parameters. To this end, Design Theory supports the cognitive abilities of designers (Verma 1997). The support is not to be understood as a prediction of results of an activity independent of context and situation, but rather support for the designer in improving his competence to

make ethic and aesthetic judgements that are appropriate in their context (Malborg & Ehn 1999).

According to Eder (1995), the purpose of designing is to take a specification of a set of needs (an idea for a new, novel, or revised process or product), and a set of statements of performances and constraints; and transform it into full instructions for manufacturing of products and/or implementing a process. Designers thus bridge thought and object (Bucciarelli 2002), design is a process to arrive from purpose to structure (Rosenmann & Gero 1998). Hubka and Eder (1988) view engineering design as knowledge-based problem solving. Some describe it as an "ill-structured problem-solving activity" (Churchman 1967, Rittel&Weber 1974), while the purpose of a required design is given by the client at the posing of a design problem, the required functions and behaviours that any design will need to manifest may not be known (Rosenmann & Gero 1998). These may, in fact, not be clarified until a certain amount of hypothesising, i.e. proposing of structure solutions is carried out. It is often so that, for design, there is no well-defined problem at hand to solve, but the problems need to be specified in the first place. This conceptual phase of any design project is potentially the most vibrant, dynamic and creative stage of the overall design process (Macmillan et al. 2000). For instance, chemical process design differs from design of many other engineering fields in that this conceptual design phase plays a central role because of the structural and behavioural complexity of chemical processes (Pohjola 1997). This complexity arises from physicochemical phenomena – phenomena referring to molecular or atomic level spontaneous events, and the conceptual design of a chemical process consists of deciding upon the control of phenomena to fulfil a purpose (Pohjola 1997).

The contents of Design Science can be structured in the form of morphology (Hubka & Schregenberger 1987) and a system of individual statements and their relationships (Hubka & Eder 1988). Table 26 shows the morphology of the statement system 'Design Science.'

Table 26. Morphology of statements on Design Science (Hubka & Eder 1988).

			State of Embodiment	ent		
Ch	aracteristic	A	В	C		
1	Methodological category of statement	Primarily descriptive	Primarily prescriptive	Normative		
2	Empirical support for statement	Pre-scientific (practice – experience)	Scientific singular – understanding	Scientific statistical (inductive)		
3	Intended recipient of statement	Novice, student	Teacher, researcher	Practitioner, designer		
4	Aspects of designing	The technical system in unstable state	The design process itself			
5	Range of objects as subject of statement	Universal: all artificial real and process systems	Technical real systems	Branch-specific objects, <i>e.g.</i> machine systems		
6	Declared aims of researcher	Automation of parts of the design process	Better empirical foundation for methodology	Others		

The 'states of embodiment' in this Table are interpreted as alternative solutions to the problem stated by the 'characteristic.' Some statements in the above Table can be adapted

to fit Waste Management Science as well. It can be asserted that Waste Management science is presented in this work as primarily descriptive, and aims at better understanding of the concepts of waste management. The intended recipients are researchers, and the aspect of designing is waste management, with the aim to describe the Waste Management System. Finally, the declared aim of this work is to provide a foundation for the Methodology of Waste Management.

Even if design tasks would seem to be domain-specific, knowledge representation might call for an ontology that describes knowledge at higher levels of generality. Given that modern design theory describes knowledge at higher levels of generality, it can be argued that Design Theory is based on ontology. As a case in point, object-oriented design of software systems depends on appropriate domain ontology. In philosophy, ontology is the study of the types of things that exist, but, today, ontology has grown beyond philosophy to mean domain-specific knowledge. Ontologies enable knowledge sharing, which, in turn, can form the basis for domain-specific knowledge-representation languages. (Chandrasekaran & Benjamins 1999.) Such a language, the PSSP language, has been introduced in Chapter 4, §4.6. Ontological commitments include the realisation that there are objects in the world, which have properties – or attributes – that take values, and they exist in relation to each other, and that there are processes in which the objects participate. In addition to simple facts, ontology can represent beliefs, goals, hypotheses, and predictions about a domain. Given a domain, its ontology forms the heart of any system of knowledge representation for that domain. (Ibid.)

In Fig. 21, design and production are shown as a stream of knowledge, which originates from the pool called Theory of Design, and continues as a Product Development Project.

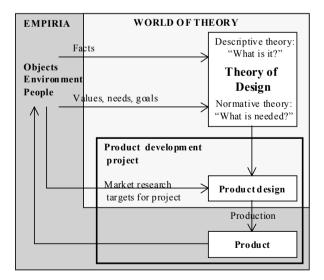


Fig. 21. The Theory of Design (Routio 2000).

With this diagram, Routio (2000) does not mean to imply that design is impossible without the help of a well-sorted design theory. On the contrary, Routio points out that there is always the traditional method of design without any explicit theories.

7.3 Theory of Technical Systems

Within the framework of Design Science, the Theory of Technical Systems (TTS) is directed to collecting, categorising and modifying knowledge related to the design objective – the Technical System. Much of the knowledge of other types within Design Science depends on this knowledge of Technical Systems, *e.g.* knowledge about designing, design procedures and methodology.

It is difficult to find a suitable term in technology for all technical works. Hubka and Eder (1988) designated the expression *systems* with particular attributes to cover all "technical means." Starting from the term 'system,' a hierarchical sub-division of systems can be achieved according to Fig. 22. Only one aspect of the origin of systems is considered herein, differentiating in the first step between artificial systems and natural ones. Hubka and Eder acknowledge that the classification of technical systems in not complete. Moreover, the boundaries between individual sub-systems is not very clear as well. As it was postulated earlier, waste management should be understood as a system composed of (1) physical things, (2) human activities, and (3) links between and within (1) and (2). In such a system, the physical things would refer to *waste-related* materials and processing devices, while the human activities would include any activities which are affected by, or have an effect on these physical things. The system was termed Waste Management System (WMS). (Pohjola & Pongrácz 1999.)

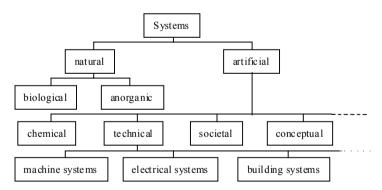


Fig. 22. Hierarchy of systems according to their origin (Hubka & Eder 1988).

WMS thus includes human activities, while Technical Systems do not include Human Systems. It would thus be difficult to place the Waste Management System on the hierarchy tree of Fig. 22. WMS also overlaps with 'technical' systems (e.g. waste-producing processes) as well as 'societal' systems (e.g. waste recovery infrastructure), while also includes 'conceptual' systems (e.g. 'what is waste?').

A Technical System represents all types of man-made artefacts, including technical products and processes. The sum of all elements and influences and the relationships among artefacts and to their environment that participate in a transformation, is collectively termed a *transformation system*. Figure 23 illustrates the model of a Transformation System.

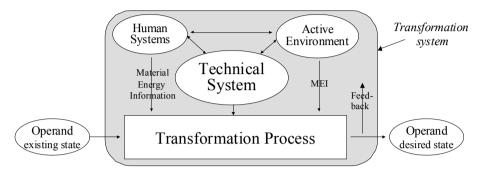


Fig. 23. Transformation system (Hubka & Eder 1988).

Each Transformation System has a well-defined Purpose: to perform the intended transformations on the appropriate operand, and thus fulfil the stated and implied needs (Hubka & Eder 1988). 'Transformation Process', as presented by Hubka and Eder can be referred to as manipulation of attributes.

A clear overview of the general manner in which these elements can be classified and ordered can be obtained from Fig. 24.

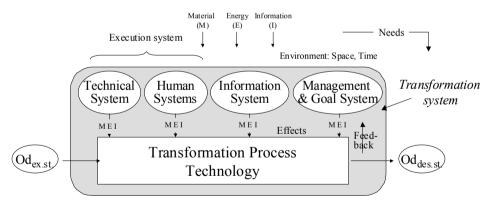


Fig. 24. Generic model of the transformation system (ex.=existing; des.= desired; st.= state) (Hubka & Eder 1988).

This generic model is fundamental in the Theory of Technical Systems. It incorporates elements of a systems-theory to explain the role of technology in society, proposed by Ropohl (1979), which shows that parts of society are themselves 'modelable' as sociotechnical systems. The Theory of Technical Systems already involves waste management considerations. Only in rare cases can a technical system release only the desired output and exclude all other outputs. Noise, vibrations, waste and heat are also generated during

the operation of a technical system. These secondary outputs depend on the mode of action of the technical system and other factors. (Hubka & Eder 1988.) They can be investigated with the aim of either avoiding such emissions, or reducing them to an acceptable minimum, or using them for a different Purpose. In any event, the tasks of engineering designers include assessing these questions of secondary inputs and outputs, keeping records abut these considerations and preferably suggesting solutions (Hubka & Eder 1992). This is another point where there is an overlap between Technological Systems and Waste Management System.

7.4 Waste Management Science

Technology is full of instances where practice has preceded theory, and the subsequent development of theory has served to improve the practice (Hubka & Eder 1988). The development of a Waste Management Science will likely follow a similar path as that of the development of Design Science. In the course of evolving Design Science, this expression raised many comments of the type: 'design cannot be science,' as design has been considered an art (Eder 1995). From the 1960s onward, the number of books and articles written on Design Science, or Design Theory, has grown from a few to hundreds per year. Still, the status and realm of Design Science have not yet been firmly established (Eekels 2001a), and one cannot say that there exists a universally-accepted Design Theory. Sargent (1994) actually proposed a meta-theoretical argument that there cannot be a unifying Design Science because there appears to be an incommensurability of viewpoints in design research. Not even the relation of Design Science and Design Theory is apparent. By some accounts, Design Science completely encompasses Design Theory (Simon 1979) and the Theory of Technical Objects (Hubka & Eder 1988). According to Love (2000), Design Theory is a sub-discipline in which the role, validity, coherence and utility of theories and concepts pertaining to design are researched, and in this subject Design Theory encompasses Design Science.

There are some apparent similarities between Design Science and Waste Management Science. Developing a Theory of Waste Management will be a long process, and starts with the disputed suggestion that waste management be elevated to science, rather than being considered a reactionary field. More than likely, a Waste Management Theory will not be developed in the way that Albert Einstein produced his Special Theory of Relativity, all alone, purely by pondering, while working in the Bern Patent Office. A science passes through various stages of maturity from the description of phenomena, through categorisation, modelling and test of phenomena to quantification (Gregory 1996). However, many areas of science cannot reach the final 'quantification' stage in which mathematical relationships are formulated (Eder 1995), which is true for both Design Science and Waste Management Science.

Hubka and Eder already noted in 1984 the difficulty of clarifying definitions when creating a novel theory. Much later, Love (2000) stated that the terminology of design research is confused. When attempting to collect a glossary of main theoretical terms of the design research literature, he found that there are almost as many different definitions of *design* and *design process* as there are writers about design. According to Love, lack of

accord within definitions of core concepts is one of the reasons why a cross-disciplinary body of theory has not developed. He urges that all key concepts by which we seek to understand design should be chosen with greater care. However, when introducing the philosophy of design, Galle (2002) suggests that a definition "carved in granite" would not be feasible, and the field is better left to grow of its own accord, without being patronised by too many preconceptions about its future identity.

One of the differences between Design Science and Waste Management Science is that while design of one particular product is specific, in waste management there are strategies that apply to a wide range of products. The designer of a Waste Management System has to abide by these rules and regulations. For instance, recycling quotas are valid for a material type, regardless of what the actual product to be recycled is. Strategies can be guidelines, or suggestions, for a potentially beneficial waste management action, but the actual strategy for one type of waste, product, or process should be designed individually.

As with any new theory, one should start with defining the scope of the theory, and define the core of its concepts. Waste management has to be planned within restrictive limits, where the choice of options is generally pre-specified. Based on Fig. 21 depicting the Theory of Design, Fig. 25 has been drawn by the author of this thesis to illustrate the scope and the influences of external factors on waste management.

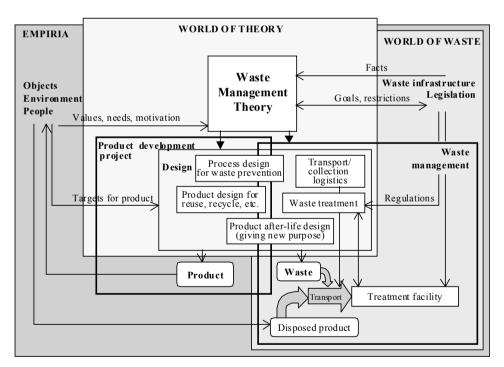


Fig. 25. The Theory of Waste Management versus the World of Waste.

The 'world of waste' is emphasised from Empiria, to highlight the influencing factors on designing waste management. It draws facts from the existing waste management

infrastructure, and is restricted by legislative constraints. However, it is hoped that there would be a communication between legislation and theory for best practical results. As proposed above, ideally, waste management design should be made for every individual product, be it for waste avoidance, treatment of process waste, or prescription/suggestion for treatments when the product turns to waste. Waste management and product development thus overlap where product/process design is concerned. As suggested by the diagram, process design should include design for waste avoidance. Initially, at the design phase of a product, consideration ought to be made of what will happen to the product after it ceases to be used for its primary Purpose. Furthermore, waste management design includes design of the logistics of waste collection, transfer and treatment.

There is one area of waste management, however, that cannot be designed: when humans dispose of unwanted things. One can model waste management, but it is not certain how the actions of individuals can be included in such a model. Given that waste is a human concept, and dependant on the needs and values of humans, there should be a Waste Management Theory explaining those concepts. The design of a Waste Management System should draw its Purpose, such as protection of environment and human health, from the Theory of Waste Management.

7.5 Purpose and causality

Needham (1927) asserted that all biological systems and all human behaviour could be explained in terms of cause and effect: a given cause produces a certain effect, and this again acts as a cause to other effects. In biology or psychology, the stimulus – response behavioural term can be used. Rignano (1926) claimed that machines could be explained entirely by cause and effect (e.g. input-output description), but biological systems require for their explanation a reference to purpose. Rosenbrock (1990) states that this debate goes back to classical antiquity, but he pointed out that from the 1950s onward, a highly developed theory of automatic control has since arisen, in which human purpose can be incorporated even into machines. However, he admits that machines embody subordinate purposes in a restricted way. Humans can adopt a purpose at a deep level, "they care whether the purpose is fulfilled or not." Rosenbrock strongly suggests that the causal view of the world be replaced with a view that embodies purpose. It is important since, as Rosenbrock puts it: "The way we explain our behaviour determines the way we behave." This resonates with the initiative hypothesis of this work: "The way we describe the target determines the way we act upon it." It was also argued that, currently, waste management is a reactionary discipline, that is, a causal activity: waste management is simply a reaction to waste.

Causality and purposiveness are merged in the PSSP approach (Pohjola 2001). In PSSP, human activity is modelled as causality, thus having cause, effect and preconditions. However, cause comes from goal, which is specified under Purpose. Hence the PSSP approach avoids the need to build any demarcation line between causality and purposiveness.

Every technological system starts from a human purpose, from the intention to satisfy some human need or desire. If so, then a policy that will implement the purpose is generated and the system is constructed so that it follows the causal laws implied by the policy. (Rosenbrock 1990.) As previously stated, the Purpose of waste management is protection of the environment and conservation of resources. This goal is the basis of describing waste management as being "control of waste-related activities, with the purpose of resources conservation and environmental protection." The argument presented in this thesis is that the causal view of waste management be replaced by a purported approach. Waste legislation, as discussed in Chapter 3, is constructed to enforce the achievement of this Purpose. Legalisation is a meta-level activity controlling waste-related activity, as illustrated in Fig. 16. This triplet of target, waste-related activity and management was argued to be a generic model of waste management (Pongrácz & Pohjola 1998).

Design is characterised as a purposeful, human cognitive activity (Rosenmann & Gero 1998). It is thus clear that design is intentional. As referred to earlier, artefacts come into being through intent (Simon 1969) and can be defined as having been intentionally made or produced for a certain purpose (Hilpinen 1999). Purpose only exists when related to human values of utility. Humans relate to artefacts through their purpose. A designer's navigation through the problem domain can be presented involving function, behaviour and structure (Gero & McNeill 1998). Rosenmann and Gero suggest that clarification of the concepts of Purpose, Function, Behaviour and Structure leads to clearer understanding of design process (Rosenmann & Gero 1998). Their modelling philosophy is rather similar to that of the PSSP, which considers Purpose, Structure, State and Performance as necessary and sufficient attributes to describe an artefact. Both modelling philosophies stem from an ontological commitment, and both follow a purposive approach. However, Rosenman and Gero do not formulate a set of ontological commitments leading to a language, while this is the case with PSSP. There are other differences between the two approaches. In Rosenmann and Gero's (1998) definition, Behaviour is a description of the object's actions or processes in given circumstances. This property in PSSP corresponds to State (Pohjola 2001), in PSSP, Behaviour can be used in place of State when describing time-variant state. Function is the result of the Behaviour, i.e. as its product or effect (Rosenmann & Gero 1998). Functionality in PSSP is embedded in the Structure of a thing. Finally, PSSP considers *Performance* for describing the 'goodness' of the thing (e.g. activity).

Rosenmann and Gero agree as well that functional modelling, which starts with assigning Purpose, can help communication between different disciplines (Rosenmann & Gero 1999). The strength of the PSSP language is in its not being domain-specific and, thus, ideally suits integration of knowledge from different disciplines. A distinctive feature is that PSSP ontology does not make any distinction between event and non-event types of things, thus permitting the treatment of activities as objects similar to objects representing things acted upon. The PSSP language is the foundation of the Phenomenon Driven Process Design Methodology, built for systematising chemical process development (Pohjola & Tanskanen 1998); the object model of the generic project (Pohjola & Bogdanoff 1999); and it was demonstrated to be a proper conceptual framework for WMS (Pohjola & Pongrácz 1999, Pohjola & Pongrácz 2000).

7.6 PSSP model of Waste Management System

The introduction of a new, scientific theory normally extends the language of science in a manner that is not purely definitional (Hempel 1973). It has been demonstrated earlier that the PSSP language can be extended to the domain of waste management (Pohjola & Pongrácz 1999), and was suggested to be the 'theory language' of waste management (Pohjola & Pongrácz 2002). More clearly, the PSSP language is an effectual tool to evolve the Theory of Waste Management and bring about its scientification.

A conceptual representation of WMS includes building conceptual representations of the waste-related things, the associated human activities, and all the relevant relationships. A PSSP model of the most general level is depicted in Fig. 26, as an object decomposing first into two, mutually communicating sub-objects, Activity and Target. The activity object is aware of the current values of the four attributes of the target object and is capable of sending messages to update these (Pohjola & Pongrácz 2002). This representation can be used as a starting point for building a generic model for waste management.

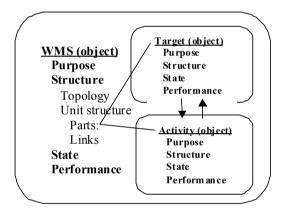


Fig. 26. Decomposition of WMS object into Activity and Target (Pohjola & Pongrácz 2002).

Since the notation used in Fig. 26 becomes cumbersome when the model is detailed, the simple object notation developed for PSSP models has been adopted (Pohjola 2001). In this notation event, non-event and composite types are distinguished by shape, and decomposition and disaggregation denoted by nesting. Using this notation, WMS can be depicted as shown in Fig. 27.

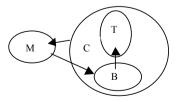


Fig. 27. Decomposition of WMS object into Activity disaggregating to Management (M) and Base-level (B) activities and Target (T) (Pohjola & Pongrácz 1999).

T represents a waste-related physical thing, and B represents a base-level activity directed to that thing. M represents the management level activity monitoring the composite (C) of B and T, and manipulating B. In the case of wastes of Classes 3 and 4 (see Table 21), T represents material identified as waste, and B represents an activity upon this waste, with an aim to turn its Purpose and/or Performance into being acceptable. This may involve manipulation of the Structure or State (including location) of waste. To avoid creation of wastes of Classes 1 and 2, the target is a not-yet-existing material, thus T represents a process, or processing device, and B represents an activity either upon an existing process/device itself (such operation or use) or upon a conceptual model of that device (e.g. design). In both cases, the aim of the base-level activity is to reduce or eliminate waste creation. (Pohjola & Pongrácz 1999.)

Consider the first case: T represents material identified as waste represented in Fig. 28. The function of the model as a simulator of a WMS can be described verbally as follows (with sub-models in Italics).

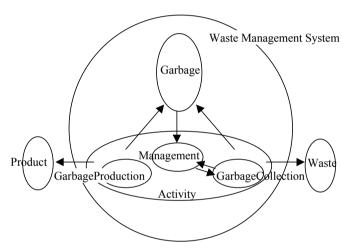


Fig. 28. Object model of Waste Management System (Pohjola & Pongrácz 2002).

Consider first GarbageProduction manipulating Product (i.e. manipulating specifications under attributes of Product). This sub-model may simulate activities upon things, which modify some properties of the things, such as emptying a milk carton, thus becoming useless to the owner. Consequently, he would want to discard it. Discarding a thing within a Waste Management System may take place by transferring the thing (empty package) to the waste basket. This is simulated by GarbageProduction manipulating Product and Garbage (i.e. manipulating the quantity of the material in InteriorMaterial, which is a sub-object of both Product and Garbage). The manager of the WMS is informed of both the quantity of garbage and the garbage collection activity. On the basis of this information, the manager controls or co-ordinates the garbage collection by specifying sub-tasks and feeding goals and resources to it. The WMS management activities are simulated by the sub-model Management monitoring Garbage and by Management monitoring and manipulating GarbageCollection. The sub-model GarbageCollection

manipulating Garbage and Waste simulates collecting material from the waste basket and transporting it further. (Pohjola & Pongrácz 2002.)

The holistic view of waste management implies integrating WMS into other related activities within society or an organisation. Suppose, as an illustration, that in an engineering company the aim is to design a manufacturing process which would include waste management issues as an integral part of the design activity. Therefore T would represent the manufacturing process, while B would represent an aggregate of the base level process design activity B_1 and another base level activity B_2 , which both refine T by specifying cycle-by-cycle its attributes with an aim to end up with an acceptable Performance of T assessed against a predefined set of performance criteria. B_2 is usually referred to as SHE activity, taking the responsibility of the Safety, Health and Environmental issues of the process. It can be disaggregated further into B_{21} and B_{22} representing Safety Engineering and Environment Protection (EP) Engineering. The management level activity disaggregates in the same way as shown in Fig. 29. This is how WMS, as a set of mutually communicating objects $\{M_{22}, B_{22}, T\}$, becomes integrated into the whole project. (Pohjola & Pongrácz 1999.)

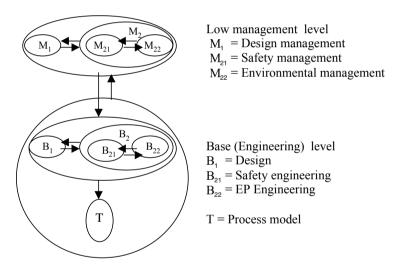


Fig. 29. Integration of waste management into design project (Pohjola & Pongrácz 1999).

7.7 The waste management domain

In science, items of information come to be associated with each other as bodies of information having the following characteristics (Shapere 1973):

- 1. The association is based on some relationship between the items;
- 2. There is something problematic about the body so related;
- 3. The above problem is an important one;
- 4. Science is "ready" to deal with the problem.

Shapere (1973) calls the bodies of information satisfying these conditions *domains*, and defines it as: "The domain is the total body of information for which, ideally, an answer to that problem is expected to account." At the conceptual schematic level of theory, the language is extended to cover the domain of the theory. The conceptual schemes relevant for the theory of waste management are verbal explanations of domain-specific concepts, expressed in the theory-language, aiming to answer the following questions that the domain of waste management consist of:

- I What is waste?
- II When does an object become waste?
- III Which objects shall be considered/treated as waste?
- IV How can waste be turned into non-waste?
- V What is non-waste?
- VI When shall we stop considering an object a waste?
- VII Can every waste be turned into non-waste?
- VIII Is there such thing as ultimate waste?
- IX What is the relationship between the concepts of artefact; non-artefact; waste; non-waste; and a natural thing?
- X What is waste management?
- XI How does waste prevention/minimisation fit into the description of waste management?

These are, indeed, very problematic issues. Additionally, these are not just independent questions, but are issues that are intricately connected and inter-related, thus together forming a system. However, there have not yet been comprehensive trials to clarify the scheme of relations in this system, and few to even answer the domain questions. To solve these problems is paramount, given that the goal of waste management is to conserve resources and protect the environment.

According to Shapere (1973), if the problem is one requiring a 'theory' as answer, the domain constitutes the total body of information which must, ideally, be accounted for by a theory which resolves that problem. There is a distinction between those problems, which are concerned with the clarification of the domain itself, and other problems calling for a 'deeper' account of the domain. Shapere refers to the former types of problems as *domain problems*, while the latter are called *theoretical problems*, inasmuch as an answer to them are called 'theories.'

The above list of questions should not be viewed as final. It is a proposition for the list of theoretical questions of the waste management domain, and it is possible to give scientifically adequate explanation to these questions. It is expected that the insight that the Theory of Waste Management would give to the domain would greatly contribute to achieving the goals of waste management: resources conservation and environment protection. The practical values of such a theory would be:

- Giving answers to conceptual questions by explaining waste and concepts;
- Providing a guide for choosing waste management options;
- Providing a foundation for how and when to select and integrate waste management options;
- Predicting the outcomes of the use of waste management actions;
- Aiding legislation in how to prescribe activity for/upon waste.

7.8 Scientific reasoning toward the theory of waste management

The following set of explanations to the domain questions presented earlier, originate from the definitions presented in Chapters 4, 5 and 6 of this work.

I What is waste?

It has been shown that there are four waste Classes (Table 21):

- Class 1 Non-wanted things, created not intended, or not avoided, with no Purpose.
- Class 2 Things that were given a finite Purpose, thus destined to become useless after fulfilling it.
- Class 3 Things with well-defined Purpose, but their Performance ceased being acceptable.
- Class 4 Things with well-defined Purpose, and acceptable Performance, but their users failed to use them for their intended Purpose.

Based on this classificatioe, the definition for waste was offered as (Definition 1):

Waste is a man-made thing that has no Purpose; or is not able to perform with respect to its Purpose.

II When does a thing become waste?

The above waste description explains the reasons why things became waste. The description of waste as "a thing which the owner failed to use for its intended Purpose," highlights the fact that it was because of the wrongful action of the owner why the thing became waste. When we describe waste emission as "a thing to which its producer has not assigned a Purpose," we point out the error of the producer. While a waste of the type: "thing which is not performing in respect to its original Purpose due to an irreversible structural change" explains the reasons why the thing became waste.

It appears that things become waste either due to a wrongful action of a human, or because of a fault in the Structure of the thing that deprives it of its functionality. Waste can thus be defined with reference to humans as (Definition 4):

Waste is a thing that is in the given time and place, in its actual Structure and State, not useful to its owner, or an output that has no owner and no Purpose.

III What things shall be considered/treated as waste?

Things that have been abandoned by their owners, because they do not wish to own them any longer, or because they do not want, or cannot be responsible for them anymore. When there is no new owner for the waste things, thus there is no one to take over the responsibility: the thing is recognised as waste. In order to prevent contamination of the environment due to the lack of a responsible owner, a waste removal company assigned by the municipality will assume ownership and take responsibility over it. The thing will then enter the waste handling process as prescribed by the authorities and performed, or overseen, by the waste management company.

IV How can waste be turned into non-waste?

Definition 1 calls for an action to turn the waste into non-waste and, intrinsically, also offers a solution for it. They are listed for each waste class in Table 27.

Table 27. Turning waste to non-waste.

Waste class	Solution to be assigned
Class 1	Waste to be assigned a Purpose.
Class 2	Waste to be assigned a second Purpose.
Class 3	Waste requires repair of Structure or adjustment of State.
Class 4	Waste requires a new owner who will use it for the intended
	Purpose, or will assign a new Purpose.

V When shall we stop considering a thing waste?

Whenever there is an owner who intends to use a thing for a Purpose. Or the owner intends to manipulate the thing to be able to perform with respect to its Purpose, it cannot be considered as waste any longer, since it does then not belong to any of the waste classes.

VI What is non-waste?

Non-waste was defined in Definition 2 as:

Non-waste is an object which has been assigned a Purpose by its (or a potential) owner, and this owner will either use it for that Purpose, or by adjustment of State or Structure, ensure that the object will be able to perform in respect to the assigned Purpose.

It was suggested that things covered by this definition shall not be considered waste, and be exempt from regulative restrictions regarding waste.

VII. Can every waste be turned into non-waste?

Conceptually, wastes of Definition 1 can be turned into non-waste of Definition 2. Naturally, we are far from the technical capacity and efficacy to actually do this in practice. There may be limitations, such as the structural damage of a thing of waste Class 3 being non-repairable, or the thing of waste Class 4 being non-retrievable. However, where applicable, we shall strive towards it.

VIII Is there such thing as ultimate waste?

There are no ultimate wastes. The life cycle of the artefact ends with it becoming a natural thing. When a waste is left to decompose or dissipate in nature, and its properties can no longer be recognised as being an artefact, it can be argued that it is a natural thing.

IX What is the relationship between the concepts of artefact; non-artefact; waste; non-waste and a natural thing?

For the purpose of this inquiry, artefacts are considered as things that were given a Purpose by humans. They can initially be natural things, with a Purpose assigned to them,

or the result of conscious human design. Non-artefacts are simply natural things. Wastes are man-made things that have a flaw in their Purpose or Performance attribute as defined by Definition 1. However, as indicated before, a waste may turn into a natural thing when it is no longer recognisable as being a man-made thing. Often, the expression 'useful object' is also applied. This simply refers to non-wastes as defined by Definition 2.

X What is waste management?

Waste management is defined by Definition 5:

Waste management is control of waste-related activities with the aim of protecting the environment and resource conservation.

Waste-related activities include waste creating processes, waste handling as well as waste utilisation. Control of these activities occurs by adjustment of the Purpose of waste, or manipulating the Structure or State of waste.

XI. How does waste minimisation fit into the description of waste management?

Prevention of waste creation is the main priority of waste management. It is in line with one of the prime goals of waste management: conservation of resources. When waste management was specified to be control of activities, it pushed attention away from already existing wastes, given that the expression 'waste management' somewhat suggests that it is merely acting upon existing waste. Industrial firms have to move toward more efficient and conscious technological choices, the consequence of which is that every product that leaves the industrial process is created for a purpose, and for an owner, and also has considerations for a second purpose, after the product fulfils its primary purpose. Ideally, this means that every product leaving the process should be a non-waste. Moving toward waste minimisation requires that the firm commits itself to increasing the proportion of non-waste leaving the process.

7.9 The methodology of waste management

The development of a waste management theory includes building a procedural model composed of waste-related activities. This model, together with the declarative model of waste, would form what will be called 'methodology of waste management.' It is a tool meant for implementing 'waste management', which is: to control waste-related activities by using a proper methodology. (Pongrácz & Pohjola 1997.)

We can accept that waste management (collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites) as defined by the Directive on Waste (European Council 1991a), is the summary of actual activity discarded things. However, planning of waste management also involves:

- strategic planning;
- decision making;
- prescribing options;

- assessing effects and consequences; and
- choosing the best treatment option, with taking into consideration legislation;
- the main goal of waste management: waste minimisation; and
- the roles of waste management: prevention of the contamination of environment, and conservation of resources

To be able to design the most appropriate waste management system, the proper theoretical background has to be established. For example, the Theory of Waste Management could be based on the following considerations:

- Waste management is to prevent waste causing harm to human health and the environment
- The primary aim of waste management is the conservation of resources.
- By applying waste management, we shall avoid loss of resources.
- Prevent waste from being produced by creating useful products (non-wastes) primarily.
- The role of waste management is to turn waste into non-waste.

Furthermore, the Theory of Waste Management consists of the following hypotheses:

- 1. Sustainable waste management depends greatly upon how waste is defined.
- 2. Waste can be represented as an object without a Purpose and/or without an owner.
- 3. Ownership over a thing is having the right and responsibility to act upon the thing that is to manipulate the properties of the thing.
- 4. The role of waste management is to give a new Purpose and/or owner to waste objects.
- 5. A sustainable process can be specified as such, where no object is created without a specified Purpose and every product is produced for an owner.
- 6. Consumer awareness can be enhanced by educating consumers about their responsibilities as owners.

Theoretical planning of waste management would then involve the methodological analysis of possible waste-related activities, by the following principles:

- Define whether the thing is waste or non-waste.
- Analyse why it become waste.
- Determine how it could have been avoided.
- Assess the consequences of this waste amount being minimised.
- Ascribe the principal consequences of the waste's existence.
- Assert whether it poses a significant health- or environmental hazard.
- Abide by international legislation in case the treatment of this thing is regulated.
- Plan waste management activities based on the roles and the goal of waste management.

It is important that a waste management option is chosen for the waste and not vice-versa. Some of the prevailing, environmental legislation creates such a situation, in which we are forced to assign waste that shall be treated by the prescribed way, even if it is not the best-preferred option to treat the waste. The present standpoint of the Community

strategy for waste management with respect to recovery operations is (European Council 1997):

"The choice of option in any particular case must have regard to environmental and economic effects, but at present, and until scientific and technological progress is made and life-cycle analyses are further developed, reuse and material recovery should be considered preferable where and insofar as they are the best environmental options."

There is a requirement for more theoretical research to be done in the waste management domain, and to offer a scientifically-founded and optimal choice of waste management options. The suggestion is that in order to chose a sustainable waste management option for a particular waste stream, the following considerations shall also be taken into account:

- 1. What was the original Purpose of the thing?
- 2. Does it entail a serious hazard to the environment?
- 3. Does it involve significant resources depletion?
- 4. Would it have been possible to avoid this becoming a waste?
- 5. Could the waste amount be reduced?
- 6. Can it be used for the same Purpose?
- 7. Can it be assigned a new Purpose without change in Structure?
- 8. Can it be assigned a new Purpose with change in Structure?
- 9. Can the energy content be recovered?
- 10. Is the net gain from the chosen waste management option worth the resources input?

Use of this methodology will be demonstrated in Chapter 8 with an analysis of plastic food-packaging.

8 Plastic food-packaging: an in-depth analysis

Packaging is a service that assist in obtaining consumer goods. Packaging, as an operation, has the function of creating sales units of the product. Packaging is made exclusively for the product's sake, not for packaging itself. The major basis of its existence is the delivery of the product to the consumer (Pongrácz 1998). The overall, negative image of packaging perhaps derives from its relatively high percentage in household waste. Table 28 illustrates Packaging Waste (PW) generation as percentage of Municipal Solid Waste (MSW), in selected countries and communities in 1994.

Table 28. Packaging waste generation in selected countries and communities in 1994 (Arango & Bertucci 1994).

	Packaging waste (PW)	PW/MSW	PW per capita
	(million tonnes)	(%)	(kg)
OECD	140.0	33	181
USA	56.8	27	210
Japan	20.0	41	163
United Kingdom	7.7	44	134
France	10.0	59	181
Germany	10.0	49	181
Italy	12.0	68	188

There is a wide variation in the percentage of packaging in MSW in OECD countries. It appears that packaging waste constitutes approximately one third of MSW. The percentage of packaging waste has not grown with the increase of MSW as illustrated in Table 2. In the U.S.A., for example, while in 1970 the percentage of packaging materials in the solid waste stream was 33.5; in 1980 it was 30.3% (Scarlett 1995). As well, in the United Kingdom in the 1975-95 period, although the volume of discarded packaging materials in the domestic waste bins had risen, the weight remained approximately the same (Porteous 1995). This may be due to lightweighting of packages, and the widespread use of plastics. Figure 30 outlines the composition of garbage in domestic wastebaskets in the United Kingdom in 1995, when the total amount of garbage was 10.22 kg/week (Porteous 1995).

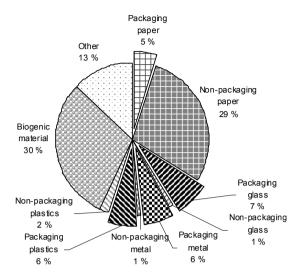


Fig. 30. The composition of garbage in domestic wastebaskets in the UK (Porteous 1995).

It seems that, on average, about a quarter of the waste in the wastebasket was packaging waste. This, however, only indicates the level of consumption. Legislation appears to view packaging waste as a great peril to be dealt with, and introduced the Packaging and Packaging Waste Directive (European Council 1993). Packages are made for the product they contain, hence they can not ever be viewed separately from the product, nor from consumption. It would mean that, if the amount of milk cartons in the wastebasket is a problem, the cause of this problem is milk consumption, not the waste package. Having left behind a 28g composite material is just one of the environmental impacts of milk consumption.

8.1 The functions of packaging

The five most important functions of packaging are listed below to give background information on packaging and for the most appropriate waste management option to be selected.

Protection function:

This function is more and more important in the present trend of increasing urbanisation. It has been concluded by the Finnish Association of Packaging Technology and Research (PTR), that the future packaging trends in Finland do not depend on materials on hand, but the more important factors of product protection and distribution. (Leppänen-Turkula *et al.* 2000). More than 150,000 people augment urban populations in developing countries every day. In the 1960s, only one third of the world's population was urban. The prediction is that by 2025, two-third of the world's people will live in cities. This means that more people will live in cities than occupied the entire planet 15 years ago.

What worsens the situation is that by 2015, the world will have 33 'megacities' with populations over 8 million, and more than 500 cities with populations of 1 million or more. Greater Tokyo already has 27 million people, Sao Paulo, Brazil 16.4 million; and Bombay, India, 15 million (World Resources Institute 1996). At such a level of immense urbanisation, distribution of goods, especially food, is crucial, and the role of packaging is enormous.

Recently, in Finland, the use of active packaging became widespread, in which packaging is combined with the use of means that assure the preservation of the product, such as protective gas, oxygen removal, etc. 'Smart' packages are also more common: the packaging includes an indicator for additional safety, with which one can follow the state of the product, such as temperature, leaking, spoilage, etc. (Leppänen-Turkula et al. 2000.)

Distribution function:

Packaging helps loading, collection and transport of the product. Distribution of bulk and liquid products is virtually impossible without packaging. Protective packaging such as bubble wrap or foam peanuts ensures safe journey. Corrugated paperboard and polystyrene foam hold expensive electronics equipment securely in their cartons and cushion them against falls, shifts and bumps. Prior to loading onto ships, trucks or planes, these cartons are stacked on pallets and wrapped with a sheet of self-clinging stretch wrap. This very strong, yet thin, film stabilises the load, keeping it from shifting and falling. Fewer falls mean reduced damage and breakage, keeping both waste and related disposal costs to a minimum. (Pongrácz 1998.)

Fragmentation of consumer markets was considered one of the major challenges of the future of Finnish packaging. Packages should function both in the traditional and new channels of distribution such as *via* the Internet. In the latter case, the package must protect the product delivered in the same transport package together with other products that may require different storage temperatures. (Korhonen 2000.)

Waste reduction function:

The role of packaging in waste reduction is the most evident in food packaging, as proper packaging of food reduces spoilage. As the use of packaging materials increases, the fraction of food waste decreases. When food is processed and packaged, the food residues are often used as fuel, animal feed or some other economically useful by-product. In absence of packaged processed food, the residues become garbage in the household. As the use of packaging materials increases, the fraction of food waste decreases. Furthermore, packaging permits food to be processed more efficiently. As an example, 50 years ago, people went to a butcher for chicken. For every 1 000 chickens sold, the butcher threw away 750 kg of feathers, viscera and other waste products (INCPEN 1987). By the 1990s, chicken producers shipped the edible parts to market and processed the rest into by-products, such as animal feed and fertiliser. It took approximately 7.7 kg of packaging to ship those 1 000 chickens to grocery stores (Testin & Vergano 1990). Overall, it was estimated that for every 1% increase of packaging, food waste decreased by about 1.6% (Scarlett 1996).

It is important to note that while increasing the product-per-package size, one can save on the packaging material as well as on the unit price of the product for the consumer, this solution is not always generally applicable. Recent trends in Finland point at the increasing number of one- and two-member families that prefer smaller packages (Korhonen 2000). Buying a large package also has the risk that the product will not be consumed within warranty time and thus will be disposed of. One ought to aim at overall waste reduction, packaging material can *not* be saved to the detriment of product spoilage and discard.

Household function:

Some packages directly enhance consumption or further preparation of the product. Probably the most famous example of packaging designed for 'easy living' is the so-called TV dinner, which allowed meals to go from freezer – to oven – to table. Today, the metal tray has been replaced by a plastic one, permitting even faster food preparation in the microwave oven. Many packages make it easy for us to use the products they contain. For example: squeezable bottles, re-closable liquid board containers, plastic bottles with handles, pop-up dispenser tops, *etc.* (Pongrácz 1998.)

It has been noted that there is a change in social trends in Finland. While home-cooked meals still hold value, few women can now afford the time it involves on a daily basis. Because of the growth in jobs held by women in the professional sector, after a busy working day, convenience calls for pre-prepared food. However, the social aspects of the family spending time together is still significant (Leppänen-Turkula *et al.* 2000). Based on interviews conducted in Finland, it was concluded that consumers anticipate growth of take-away dining in the future, which will increase the demand for convenience packages in which the food can be delivered, heated and served by the consumers (Korhonen, 2000).

Value-forming function:

From the economic point of view, packaging has a very important role in the sale process. There is value-forming carried on by adjusting the usage and æsthetic values of the product to the consumer with the package. Without packaging, many products, especially bulk products, simply cannot be easily sold. For instance, a barrel full of toothpaste has no purchase value, since who would want to buy it? Portioning it into squeezable tubes, however, makes it possible to sell, thus packaging creates value for toothpaste. (Pongrácz, 1998). It was also concluded by PTR that, in Finland, the role of packaging as a marketing tool will be strengthened in the future (Korhonen, 2000).

8.2 Waste management methodology for plastic packaging

As stated in Chapter 7, a waste management option is chosen *for* the waste, not *viceversa*. If one accepts the definition of waste management, as prescribed by Definition 5, then one shall see that waste management practices abide by this goal. From all packaging, plastics – especially non-refillable sturdy plastic containers – have the most

negative image. They are difficult to recover, and their recycling is problematic. Consider as a case in point: the sturdy, plastic butter/margarine tub. In Finland, a great variety of margarine, butter, butter-vegetable fat mix, and other sandwich-spreads are sold in plastic tubs, generally holding 400g of the product, as presented in Fig. 31.



Fig. 31. Plastic butter/margarine tub, 400g (Valio 2002).

When considering waste management for this tub, that is, how to minimise resources use, and avoid pollution, one has to methodically go through the set of roles as described in Chapter 7.

What was its original Purpose?

To deliver the product it contained to the consumer.

Why did this thing become waste?

It is waste of Class 2: it has fulfilled its single finite function.

Would it have been possible to avoid this becoming a waste?

It has fulfilled its Purpose, and has not yet been designed to have another one. Without a second purpose, the tub's becoming waste could only have been avoided if the margarine was not packed into those tubs. Butter and baking margarine are wrapped in aluminium-paper foil in 500g units. Margarine, especially with lower fat content, however, is not solid enough to be handled wrapped in blocks. It will also, most likely, be kept for an extended period in the refrigerator due to its relatively long warranty time and low frequency of usage. According to Mr. Leo Junkkarinen (2002) of Valio's (Finnish milk processing company) R&D Department, this packaging form was chosen to ease the handling of the product by the consumer and give sufficient protection to the product. If this is the most efficient way of delivering the product, altering the package is not a preferable option.

Does it entail a serious hazard to the environment?

It is made of an inert plastic (HDPE) which does not pose an immediate hazard. However, it can be an æsthetic nuisance if it is seen as litter.

Does it involve significant resources depletion?

It was estimated that in Finland, about 52% of all plastics were used for packaging purposes (Kärhä 1994), and plastics are of fossil origin, so this may suggest that plastic

packaging use depletes fossil resources. In 1995, about 220 000 tonnes of plastics were used for packaging purposes (PTR 1996), which is about 44 kg per person. As the negative image of plastics is due to their fossil origin, it is useful to compare the fossil content of plastics to that of gasoline. Table 29 summarises the oil- and other product-related energy parts of plastics.

Table 29. Energy use of plastics production in MJ/kg (Engelbeen 1996).

Material	Total ^a	Oil	Other
PVC	53	24	29
PE	70	55	15
PP	73	58	15
PS	80	55	25
PET	84	31	53
PC	107	36	71

a.Source for total energy use: Environmental Defence Group of The Netherlands. 1991. Environmentally friendly packaging in the future

The figures in Table 29 include the average energy efficiency of mixed electricity generation in Europe (about 40%). If more low-efficiency electricity is used, for example nuclear (31%), the "Other" figures will be higher. If high-efficiency electricity generation is used, for example co-generation (approximately 90%), or hydropower (87%), they will be lower. With a 90% efficiency at the source and 8% energy use, 1 litre of petrol (0.76 kg) needs approximately 0.9 kg of crude oil, with 1 kg crude oil counted for 44 MJ/kg. (Engelbeen 1996.) This gives a plastics-to-petrol ratio in kilogram per litres, as shown in Table 30.

Table 30. Plastics-to-petrol ratio for different plastics (kg/l) (Engelbeen 1996).

Material	Minimum	Maximum
PVC	0.75	1.65
PE	0.57	0.72
PP	0.54	0.68
PS	0.50	0.72
PET	0.47	1.28
PC	0.37	1.10

The plastics-to-petrol ratio is of minimum value in Table 30, when the "Other" figures of Table 29 are counted as oil-based. "Maximum" values are when all "Other" are not oil-based. PVC and PC, in reality, will be more to the "Maximum" side because of relatively high electricity consumption, mainly not produced from oil, and low oil base as feedstock. For PE, PP and PS, the balance is more towards the "Minimum," because they are more oil-dependent. PET is somewhere in between. This, however, depends very strongly on the (inter)national, or local and, sometimes, on-site electricity production (Engelbeen 1996). This calculation is based on how much crude oil is directly used for production of plastic and gasoline. With this calculation, the plastics-to-petrol ratio is, on average, 0.88 kg/litre. Thus, the average Finnish national's yearly plastic packaging consumption amounts to 50 litres (38 kg) of gasoline in fossil material content. In 1995, 1

896 965 tonnes of gasoline were sold to consumers in Finland (Statistics Finland 1998). Consequently, the 220 000 tonnes of plastics, which in fossil content amount to 193 600 litres of gasoline, is about 10% of the yearly gasoline consumption by consumers. This would also mean that a 10% improvement of the mileage of cars, or 10% decrease of car use, or a combination of both, could offset the whole year's plastic packaging use. These calculations were made for all plastic packages, while only a fraction of them are margarine tubs. The Valio company uses approximately 540 000 kilograms of plastic tubs for butter and margarine yearly (Junkkarinen 2002). The gasoline sold to consumers is only a fraction of all fossil-based fuels used in Finland. This calculation is only meant to be illustrative, to give a basis for comparison. The conclusion is that the plastic margarine tub is not the major fossil source depletive.

Could the waste amount be reduced?

In this case, the more precise question would be: could the same amount of product be delivered with less packaging material? In theory, it is possible to make the tub walls thinner. A study on packaging efficiency (Lilienfeld 1995) concluded that reducing packaging weight offers significant opportunities to minimise discards and thus conserve resources. The study indicated that, regardless of materials used, reducing the amount of packaging material needed to deliver a given amount of finished product is an excellent strategy for minimising waste. Lightweighting can provide greater benefits than those achieved by relying solely on recycling. Due to this, product-to-package weight ratios tend to be more accurate measures of diversion efficiency than are recycling rates. It should be assessed, however, whether the protection level of the package is still acceptable. Reducing the package weight and perhaps increasing product loss due to breakage is not a preferable option.

In this case, the thickness of the tub wall has been optimised, based on consumer requirements (Junkkarinen 2002). The wall thickness can only be reduced in as far as it still gives sufficient protection to the product and is strong enough for handling. The weight of a margarine tub, with lid, is about 20 g (Ibid.). Therefore, additional reduction can only be in the area of a couple of grams, while the potential product loss would be 400 g. Considering that in the case of Voimariini, the packaging price is 8,5% of the product's ticket price (Junkkarinen 2002), it is not worth saving packaging material at the expense of safe product containment. Extreme measures designed to reduce packaging may have the effect of reducing the use of paper, metals, glass and plastics at the expense of the food they would have protected, despite the value of the wasted food being many times greater than the value of the now-avoided packaging (WRF 1995). One ought to bear in mind, however, that the primary package is only one part of the distribution chain. The products packed in primary packaging are collected in secondary packages, generally cardboard boxes. It has been observed that when the primary packages are lightweighted, the amount of secondary packages had to be increased for the best product protection (Gladden 1992). The overall benefit of package lightweighting has to thus be carefully

Another solution is to reduce the packaging-to-service ratio, rather than the packaging-to-product ratio. This means that the product is concentrated, thus offering more service with less material. It is not viable in the case of margarine, but it has been the conclusion

of the above packaging efficiency study (Lilienfeld 1995), that for an effective resources use, product distribution should move toward product concentration; for example, by removing water from products, such as detergents, drinks, *etc.* In the case of liquid detergents, it was reported to save up to 41 % of packaging material (Samuel 1992).

The third route is through package design. This would mean using computer-aided design in developing, for instance, new bottle shapes. Subtle changes in shape result in a significant reduction in packaging material consumption, although not always perceivable by the consumer.

Can it be used for the same Purpose?

Some packages are refillable but most are not, given that package re-use was not built in at the design stage. One possibility is to consider if margarine could be offered in a refillable package. This involves a basic consideration of logistics – how is it possible? Market research would also be required to determine how consumers would accept such a new option. It would involve re-design of the package, changing the filling machinery, organising the collection of the empty packages, and washing and sterilising the package, which requires, most probably, fossil-based energy. It was shown that for every kilogram of domestic plastic packaging washed at home, 78 liters of hot water and 0.4 kg of fuel for heating the water were needed. Altogether, it is estimated that the total fuel needed to wash, collect and recycle a kilogram of plastic is in an area if 1 kg of fuel (Williams 1995). It is then debatable if it is worthwhile refilling margarine tubs for the same Purpose to save on packaging material.

Can it be assigned a new Purpose without Structural change?

Some packages can be used for a new Purpose, which is generally assigned by the consumer. One could use the margarine tub as a 'lunch-box;' as a container to freeze berries in; as a gadget box, keeping buttons, nails, and/or other small items, in it, *etc*. However, one has a limited need of plastic tubs, while at the same time there is a continuous need of the product (margarine) it originally contained. Most probably, this solution cannot be 'institutionalised' or designed at a conceptual level. Consumer awareness, however, could be raised by recommending second-use options.

Can it be assigned a new Purpose with Structural change?

This calls for recycling or other material recovery. Indeed, the European Packaging and Packaging Waste Directive (European Council 1991a) encourages mechanical recycling. however, APME (1995), qioted in §2.2.5 of this work, concluded that mechanical recycling processes have ecological advantages over feedstock and energy recovery processes only if 'virgin' plastic is substituted in a ratio of 1:1. This would mean that the European Council's legislation, which insists that at least 15% of the waste plastics packaging be mechanically recycled (European Council 1991a), enforces an ecologically non-preferable option. The decision of whether mechanical or feedstock recycling is used should be made on-site, based on the region's specific conditions, such as recycling infrastructure, transportation distances, whether there is an accommodating metallurgy industry in vicinity, availability of thermolysis, *etc*.

Can the energy content be recovered?

In Finland, according to the statement of the Packaging Research Institute's study (Manninen *et al.* 1996), the amount of different post-consumer packaging waste fragments are so small that separate recycling programmes for most products are neither ecologically nor economically feasible. In Finland, there is a long tradition of burning packaging materials in households, especially in the traditional wood-heated saunastoves. There is only one waste incineration plant, located in Turku in south-western Finland. The same study also investigated the use of different types of packaging waste as a secondary fuel in a circulating fluidised bed (CFB) boiler. The main conclusion of the study was that the combustible fraction of waste materials, mainly consisting of used packages, can be safely utilised as co-fuel in modern power plants, as up to 20% of the thermal feed with fossil fuels. The local utilisation would save energy in transportation. With some of the tested packaging waste, there were feed problems, which has also been the observation of the local power plant. However, it is only a matter of technology to overcome this problem.

A possible solution was suggested by Kiviahde in Pongrácz *et al.* (2000). The recommendation was to develop a processing configuration for sintering (partially melting and compressing) plastic waste to produce fuel briquettes. These briquettes could be later used as fuel components along with peat and wood. A remarkable benefit of the briquetting method is that the use of this type of fuel will not require auxiliary installations for the fuel conveyor systems at the power plant. Peat, wood and combustible solid waste could be burned in the small-scale incinerator. At the same time, plastic waste can be sintered into briquettes using the thermal energy of the flue gas. The processing unit could be attached to a fluidised bed boiler, while the thermal energy released by the process can also be recovered. Mixing crushed paper and paperboard waste with partially melted plastic mass could also be investigated in order to produce fuel briquettes of mixed plastic and paper waste. These briquettes could also be later used as fuel components in conjunction with peat and wood.

Feedstock recycling options could also be considered. According to the study by APME (1995), from an ecological point of view, the best recovery option for waste plastics is use as reducing agents in blast furnaces, thermolysis-to-petrochemical products or fluidized-bed combustion. Accordingly, the best energy recovery option will be chosen based on local conditions.

There are major steelmaking factories in the vicinity of Oulu, *e.g.* the Rautaruukki Raahe Steel concern in Raahe is less than 100 km away. It was suggested that using plastics to replace heavy fuel in steelmaking is, ecologically, the most preferred option of plastics recovery. It can be concluded that there is great potential in Northern Finland for feedstock recycling of plastic packaging waste.

Is the net gain of the chosen waste management option worth the resources input?

Figure 11 illustrated the journey of recyclables from Oulu in 1999. During that year, plastic waste collected from households was transported from Oulu to Suomussalmi for incineration. According to the report in the local newspaper, *Kaleva* (Vuollo 1999), not a single waste transport vehicle has managed to be fully loaded when transferring plastic waste. As the head of Oulu's Waste Management Company, Oulun Jätehuolto, Mr.

Markku Illikainen estimated, in Oulu, 4,000 tonnes of plastic waste is produced yearly. This is about 10% of total municipal solid waste. From this, about 200 tonnes were recovered from separate waste collection containers. In 1999, there were 13 drop-in centres for waste plastics in Oulu. From these collection points, the plastic waste was collected and transferred to the Rusko waste transfer station, where they were then baled. The baled waste was then transported about 200 km to Suomussalmi, where the bales were torn apart, and the waste plastics were transferred to be burnt in the nearby Ämmänsaari thermal power plant, mixed in with other fuel. The article concluded that recovery of plastics in this manner is not cheap: the collection, the baling, and the transport constitute a considerable cost, while Oulu does not gain any benefit from the plastics at all. Illikainen suggested that, in principle, the plastics could have been incinerated in Oulu, but the city was not successful in negotiating with local companies. There was also much criticism directed at the Oulu Waste Management Company for not putting more effort into finding a local receiving company, nor did they explore the possibilities of other utilisation locally. (Vuollo 1999.)

In conclusion, considerable costs and inherent environmental stress is involved in transporting a minor amount of waste over 200 kilometres for recovery, thus the net benefit of present valorising plastic waste is arguable.

8.2.1 Recommendations for the presented plastic packaging

After the foregoing analysis, the recommendation to the given company is to motivate and encourage consumers concerning re-use of their sturdy, plastic packaging in the household. The shape and outlook can be made more attractive and fitting for home-usage, ideas could eventually be sought from consumers as part of a competition-for-reward strategy. Consumers ought to be advised about recovery on the package as well as other options. For instance, if the Finnish consumer wishes to take this packaging for recovery, he should be made aware not to use excessive amount of hot water for washing the empty package.

Material recycling for this plastic package, given the local conditions in Oulu, is not advisable. Several other utilisation options are recommended, such as thermolysis or briquetting of mixed non-recyclable plastic and paper waste, the briquettes to be used locally for heating or energy generation purposes. Another possibility is pyrolysis of mixed plastic waste and use of pyrolytic oil by a steel factory. Building of a regional Industrial Ecology network is promoted.

In either of the recovery cases, the level of cleaning needed will be carefully considered. For example, if margarine boxes will not be mechanically recycled, it may not be necessarily to wash them with hot water. It may be sufficient to wipe the box with a soft tissue, thence disposing the tissue in the bio-waste.

The knowledge to be gained from this case shows that if a solution that is to lead toward resources conservation and protection of the environment is to be found, a waste management option should be chosen based on a conceptual and methodological analysis of the target. Careful consideration of the consequences of activity upon the target must be taken into account as well.

9 Summary

Waste management is often viewed as the last step of the material chain. In actuality, waste management is part of resources management. Quantities of waste can be seen as an indicator of the material efficiency of society. Waste generation in the European Union amounts to approximately 1 300 million tonnes a year. Waste represents an enormous loss of resources both in the form of materials and of energy. However, the environmental impact of waste cannot be analysed by looking at quantity alone. Dangerous substances in waste, even in small quantities, can have a very negative impact on the environment. The most important — and largest sources of waste — are manufacturing wastes, and construction and demolition waste, the latter being one of the priority waste streams of the Community. The main strategy for manufacturing waste is prevention and reducing the hazard of waste. While for construction and demolition waste, the main aim is to improve recycling activities, given that the overall political target to prevent waste generation from increasing has only few chances due to construction being viewed as an indicator of growth and prosperity in Western societies.

There is an assumption that waste management options can be placed on a fixed order of priority, often referred to as the 'solid waste management hierarchy' which is: waste prevention, recovery, and safe disposal. It has been previously noted that the hierarchy is to be listed as waste minimisation, re-use, recycling, incineration and disposal. Waste minimisation includes: waste prevention *i.e.* reduction of waste by application of more efficient production technologies, internal recycling of production waste, source-oriented improvement of waste quality, *e.g.* substitution of hazardous substances, and finally, re-use of products or parts of products for the same purpose.

The importance of waste minimisation is emphasised. While the principle of waste prevention is universally accepted, the practice has lagged far behind. It was concluded that there is much to be learned about reducing waste, and "efficiency is the cure for the wasting disease" (von Weizsäcker *et al.* 1997). Information and motivation play important roles in waste avoidance. Consumers, given eco-efficient choices, also play an important role in resources conservation. However, this requires not only education but also opportunities and incentives. These issues have to be addressed if society is to move toward sustainability.

'Re-use for the same purpose' is included in waste prevention, but 're-use for another purpose' is not; it is listed as recovery option by ETC/W. As well, occasionally mention of 're-use for another purpose,' in various legislation does not appear to be re-use at all. However, this is difficult to assess, given that there is no definition for 're-use for another purpose.' The available 're-use' and 'recycling' definitions both appear to assume that the waste thing previously had some Purpose and for some reason ceased to be used for that Purpose. However, in many cases, waste is an emerging new product that has not had a Purpose. In that case, one can *not* use it for the *same* Purpose, and it can not be given a *new* Purpose: one can only ascribe its *first* Purpose. To fill this void, separate definitions for 're-use for the same Purpose' and 're-use for a new Purpose' are offered. It is also suggested that both are to be considered as waste prevention options.

The concept of recycling to conserve resources is based on the assumption that recycling requires fewer raw materials and less energy, and generates fewer emissions into the environment, than manufacturing new material. However, recycling is not environmentally sound when additional transportation steps, using non-renewable fossil fuels, must be used to collect the material prior to recycling. It is important to stress that while recycling is a mechanism for achieving environmental goals, it should not become a goal in and of itself. Furthermore, recycling has its economic as well as technical limits, especially for plastics. As an alternative, feedstock recycling is discussed, and it was cited that mechanical recycling processes have ecological advantages over feedstock and energy recovery processes, if 'virgin' plastic is substituted in a ratio of 1:1.

In the order of least desirable options, incineration is considered as an alternative to disposal. Nevertheless, there are many advocates of incineration given that it reduces the volume of the waste, the product is guaranteed to have a market, and it does not require major alteration in the waste collection system. However, due to potentially dangerous emissions and limitations in humidity of the input for incineration, thermolysis is mentioned as being a preferable alternative to energy recovery of mixed waste.

It was noted that modern landfill technology is highly advanced and thoroughly researched. A revolutionary new landfill system, the Aerobic Landfill System (ALS), is mentioned as a new prospective for landfilling waste.

European action in the waste field has mainly taken the form of legislation. The main goal is protection of the environment and natural resources. The general approach and strategy is described in the Sixth Environmental Action Programme. It focuses on four priority areas for action: climate change; biodiversity; environment and health; and sustainable management of resources and wastes. The objective is to ensure that the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment, and to achieve a decoupling of resource use from economic growth through significantly improved resource efficiency and the reduction of waste.

The most important waste-related regulations at the EU level are: Regulation on the Supervision and Control of Transfrontier Waste Shipments, Directive on Packaging and Packaging Waste; Directive on Integrated Pollution Prevention and Control; the Directive on the Landfill of Waste; Directive on End-of-Life Vehicles; and the Directive on Waste Electrical and Electronic Equipment. The EU has firm principles which are included in its approach to waste management: Prevention-, Precaution-, Proximity-, Producer Responsibility- and Polluter Pays Principles. It is agreed that common terminology and a definition of waste are needed in order to improve the efficiency of waste management in

the Community. To that end, the Waste Directive defined waste as: "any substance or object in the categories set out in Annex I which the holder discards, or intends, or is required to discard." Waste management was defined in the same Directive as "the collection, transport, recovery and disposal of waste, including the supervision of such operations and after-care of disposal sites."

In Finland, the National Waste Management Plan, which came into force in 1998, prescribed that by the year 2005, the recovery rate of 70% should be exceeded. However, a study on national separation strategies concluded that recovery rates around 35-50%wt are more realistic and that the national recovery rate targets should also be divided into regional sub-targets. In a sparsely populated country such as Finland, with a large share of detached houses, such regulation does not contribute to effective use of resources. In Finland, the environmental problems of cities are handled more successfully than those of the countryside. As a case in point, Oulu City's Waste Decree advocates separate waste collection at source. Housing, with at least four apartments, must provide separate waste collection containers, besides for mixed waste, for paper waste and bio-waste. Housing with at least ten apartments must supply additional containers for cardboard packaging. However, as the recycling industry is mainly situated in the South of the country, some recyclables travel up to 400 km to recycling facilities.

In Finland, glass, plastic and cardboard recycling are experienced as the most problematic due to high collection costs contrasted with the low retail value of glass; high volume *versus* low weight of cardboard; and difficulties in separating different types of plastics. Paper recycling in Finland is prescribed by law, thus is practised throughout the country. Consequently, in 2001 the waste paper recovery rate was 74%. However, one cannot help but question if the price of this success was too high for the environment, because mixed waste paper from the most remote points of the country travel up to 1 000 kilometres to the recycling facility. It is reiterated that the Finnish environment is not uniform; no practice could ever be tailored to fit each area of the country. Waste strategies should be decided at the local level, utilising specific knowledge of regional conditions.

Extended Producer Responsibility was initiated by the German Packaging Ordinance. It led to the European Council Directive on Packaging and Packaging Waste due to claims of landfill shortage and packaging waste amounting to a significant percentage of the municipal waste stream. However, contrary to popular belief, this does not mean that packaging waste is flooding landfills. Some call this belief a 'myth' and question the worth of recycling packaging. It was concluded that, while there was an increase in the level of recycling in the European Union, the amount of municipal waste landfilled is still rising. Waste legislation has not managed to reduce the amount of waste either in Finland, or in the European Union. It was concluded that the challenge of reducing the quantities of waste could not be solved by recycling alone. Recycling addresses only the disposal of a product when it becomes waste, rather than its generation, thus it only recovers the energy and material included in the product, whereas prevention addresses the energy and materials use of the whole production chain. Waste must be analysed and handled as an integrated part of total material flow through society. Waste management is part of the global context: an integrated approach including reduction of waste, energy efficiency, pollution prevention and water-use optimisation is urgently required.

It was argued that present, official, legally-accepted waste definitions in Europe do not describe waste appropriately. If, however, there is no sufficient definition for waste, it is then difficult to determine waste from non-waste. The official definitions suggest that waste is something that its holder disposed of, thus legislation appears to deal with existing waste and is concerned with how to treat it. It was noted that this is a very useful and understandable attitude: the main goals of the existing European legislation on waste are the protection of public health, the environment and natural resources. The European Commission also recognises that to date, there is no satisfactory definition of when a product becomes waste, nor when a waste becomes a product again. Industry calls for developing criteria to distinguish by-products from waste. Recycling companies often find the 'definition of waste' as an obstacle to environmental protection, given that wastes are subject to more stringent restrictions regarding their transport and processing, resulting in increased costs. Under the definition of waste, recoverable material is seen more as a potential pollutant than as a potential raw material. There appears to be an emerging recognition within some Member States that waste collected for recycling purposes should be defined as a secondary raw material - a non-waste - so that it can compete with virgin resources on a cost-effective basis.

Using the PSSP language as a tool, it was demonstrated that there are four waste classes. Non-wanted things, created but not intended, or not avoided, with no Purpose; things that were given a finite Purpose, thus destined to become useless after fulfilling it; things with a well-defined Purpose but their Performance ceased being acceptable; things with a well-defined Purpose and acceptable Performance, but their users failed to use them for their intended Purpose. Based on this classification of waste, the definition for waste was offered as:

Waste is a man-made thing that has no Purpose; or is not able to perform with respect to its Purpose.

This type of waste description calls for the possibility of the waste being turned into non-waste. It was reiterated that waste is not necessarily a material thing, and the concept of waste shall not be confused with, for example, 'garbage.' If society's goal is a sustainable world where resources are to be used effectively, it means that no unnecessary wasting shall take place. It is reminded tht waste isn't inherently bad, it is wasting, what is bad. It was highlighted that waste in itself is not detrimental, but the act of wasting is.

It was the fourth class of waste that prompted the introduction of the concept of ownership. Ownership over a thing was defined as 'a right and a responsibility to act upon the object, that is to manipulate the properties of the thing.' Ownership in waste management thus becomes somewhat of an ethical issue, and more stress is placed upon responsibility. Some in the field argue that waste can be defined by only referring to an owner. It was concluded, however, that ownership alone is not sufficient to define waste, it is also a function of Purpose. Alternatively, waste can then be presented as a thing with a given Purpose but without an owner, or simply as a thing without a specified Purpose. With respect to the owner the dynamic nature of waste can be defined as:

Waste is a man-made thing that is in the given time and place, in its actual Structure and State, not useful to its owner.

The impact of the concept of waste management is analysed. It was seen that the need of the concept of ownership is necessary to remind people of their responsibilities over the waste they create. The Polluter Pays Principle should be broadened in its application.

Everyone ought to be aware that, when purchasing a thing, one acquires the rights and the responsibilities for that thing. To act as responsible owners, consumers should opt for durable products as opposed to short-life, or single-use ones, look for the opportunity to donate or trade still-useful objects, and support waste recovery systems, which ensure that waste is utilised.

Depending on the nature of a waste, owners may be restricted in their right to freely give up ownership. The role of legislation is to decide, evaluate and monitor the conditions under which owners can give up their ownership. Water and air pollution emissions – jointly referred to as effluent taxes, waste or landfill taxes, regulations on hazardous waste disposal, are some examples of legal restrictions to abandoning ownership.

The initiative hypothesis of this dissertation was that the way in which waste is described, prescribes how it is going to be handled and, consequently, effective waste management greatly depends upon how waste is defined. Since it was stated that waste is a thing without an owner or without a Purpose, the *role of waste management* was defined as:

Finding new ownership and/or giving a new Purpose to the waste.

By way of explicating why something becomes a waste, the definition intrinsically also offers a solution as to how a waste object can be turned to non-waste – assuming that it is retrievable.

Non-waste was defined as a thing, which has been assigned a Purpose by its, or a potential owner, and this owner will either use it for that Purpose, or by adjustment of State or Structure, ensure that the object will be able to perform in respect to the assigned Purpose.

Theoretically, every waste can be turned into non-waste. This should be of the highest priority for waste management, but there is no 'alchemy of waste management,' and we cannot upgrade every waste into a higher value thing. There are no ultimate wastes either. The life cycle of the artefact ends with it reverting to a natural thing. Landfill however, does not turn wastes into non-wastes and it is not a manipulation of a waste thing with definable attributes, rather it is an aggregate, unidentifiable mass of things. The Purpose of the landfill is simply to take over the responsibility from the primary owners over their non-wanted things, it does not necessarily give a Purpose to the waste. At best, landfill can be viewed as a temporary storage with the hope of landfill mining in the future for recovery of useful components, and ultimately giving Purpose to them.

There is a conflict between differing legal interpretations of waste management. The definition of waste management suggests its role to be merely to do away with existing waste, while the hierarchy proposes that, ideally, we should avoid creating waste. In response to this conflict, a new definition for waste management was offered:

Waste management is control of waste-related activities with the aim of protecting public health and the environment and resources conservation.

The role of legislation is to oversee that waste management fulfils its goal of resources conservation and environmental protection. Legislation can thus be considered as a metalevel activity which monitors the base level activity and sets targets for activity upon waste, *e.g.* by fixing recycling rates to be achieved, setting targets to reduce emissions, *etc.* It was also indicated that while recycling has an important role, it ought not be regulated by fixed rates, and there is a need for re-thinking priorities and target groups.

Waste management is often extended to integrated resources management, in order to avoid the negative image associated with wastes. The purpose of an integrated material policy should be to ensure safe handling of all materials regardless at which point they are in their life cycle. Priority shall be given to waste minimisation in industry and resources optimisation in general.

It was suggested that waste management is bound to the paradigm of Industrial Ecology (IE). The goals of IE can be expressed in terms suggested in this thesis: the industry shall strive toward there not being a product without a Purpose leaving the process, and that every product would have an owner. Furthermore, after the product has fulfilled its Purpose, or does not perform in accordance with its Purpose, it should be assigned a new Purpose.

It has been illustrated that waste is a human-related concept, calling for it to be analysed conceptually. Constructing the Theory of Waste Management is a decisive step towards the scientification of waste management. While most theories are from the fields empirical sciences, or the philosophy of science, new scientific specialities may emerge from previously practical fields, such as Design Science. Design Science is an attempt to provide a general, comprehensive theory of designing. It was considered that the development of Waste Management Science would follow the same path as that of Design Science. There are several similarities between Design Science and Waste Management Science. However, while design of one particular product is specific, in waste management, there are strategies that apply to a wide range of products.

Within the framework of Design Science, the Theory of Technical Systems is directed to collecting, categorising and modifying knowledge related to the design objective – the Technical System. It was postulated that waste management should be understood as a system composed of physical things, human activities and links between them. This system was termed Waste Management System (WMS). WMS thus includes human activities, while Technical Systems do not include Human Systems. However, WMS overlaps with technical systems as well as with societal systems, while it also includes conceptual systems. On the other hand, the Theory of Technical Systems already involves waste management considerations. Technical Systems release waste, noise, vibrations and heat. Technical Systems thus can be investigated with the aim of either avoiding such emissions, or reducing them to an acceptable minimum, or using them for a different Purpose.

It was argued that, currently, waste management is a reactionary discipline, that is, a causal activity: waste management is simply a reaction to waste. It was suggested that waste management should embody a Purpose. Causality and purposiveness are merged in the PSSP approach: In PSSP, human activity is modelled as causality, however, cause comes from goal, which is specified under Purpose. Hence the PSSP approach avoids the need to build any demarcation between causality and purposiveness.

The PSSP language was suggested to be the 'theory language' of waste management. A conceptual representation of WMS was presented and proposed to be a starting point for building a generic model for waste management. Two different levels of waste manipulation activities were presented using the PSSP model. In the garbage disposal model, control of a waste-related activity happens through interaction with existing waste. To prevent waste being created, manufacturing activity has to be controlled. To this end, a model of integrating waste management issues into manufacturing activity was offered.

Waste management theory, as differentiated from waste management practice, represents a more in-depth account of the domain and contains conceptual analyses of waste, the activity upon waste, and a holistic view of the functions and goals of waste management. The contributions of this work to evolving the Theory of Waste Management are: a conceptual description of waste management, providing definitions of all waste-related concepts and suggesting a methodology of waste management. A domain-specific set of problems is put forward and described, with their relationship explained, thus providing a system of logically interconnected knowledge sets.

It was argued that the domain questions of waste management have not been adequately addressed, and that the scheme of relations in this system have not been explained comprehensively. A listing of domain questions was put forward, and it was claimed that when one is looking for a scientific systematisation, and ultimately aiming at establishing an explanatory and predictive order among the domain problems of waste management, a theory is required. However, it was also recognised that the list is not complete, it is but a framework. There are many more questions that belong to the domain of waste management that such a framework would need to be supplemented. Nevertheless, it is expected that the insight that a Theory of Waste Management would greatly contribute to achieving the goals of waste management

The Theory of Waste Management is founded on the proceeding expectations:

- Waste management is to prevent that waste causes harm to human health and the environment.
- The primary aim of waste management is the conservation of (natural) resources. By applying waste management, we shall avoid loss of resources.
- We shall prevent waste from being produced by producing useful products nonwastes – primarily.
- The role of waste management is to turn waste into non-waste.

It was suggested that theoretical planning of waste management involves the methodological analysis of possible waste-related activities by the following principles. Define whether the thing is waste or non-waste and analyse why it became a waste. Furthermore, determine how it could have been avoided and assess the consequences of this waste amount being minimised. One shall ascribe the principal consequences of the waste's existence by asserting whether it poses a significant health- or environmental hazard. Finally, based on these considerations, waste management activities shall be planned in concert with international legislation.

It was concluded that there is a need for more theoretical research to be made in the waste management domain, and to offer a scientifically-founded and optimal choice of waste management options. A treatment option should always be chosen for the waste not *vice-versa*. It was suggested that, in order to chose a sustainable waste management option for the waste, the following questions should be methodologically answered:

- 1. What was its original Purpose?
- 2. Does it entail a serious hazard to the environment?
- 3. Does it involve significant resources depletion?
- 4. Would it have been possible to avoid this becoming a waste?
- 5. Could the waste amount be reduced?
- 6. Can it be used for the same Purpose?

- 7. Can it be assigned a new Purpose without structural change?
- 8. Can it be assigned a new Purpose with structural change?
- 9. Can the energy content be recovered?
- 10. Is the net gain from the chosen waste management option worth the resources input?

The above-mentioned set of questions was answered in the analysis of sturdy plastic food packaging in Northern Finland. It was concluded that recycling is not the most optimal method of handling this waste. Primarily, consumers ought to be encouraged to re-use the packaging at home. They also ought to be advised against using excessive amounts of hot water in washing empty packages when recovery is planned. It was suggested that, in Northern Finland, feedstock recycling methods be used for recovering the fossil content of plastic waste.

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