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412 96 Göteborg

ISSN 0280 - 4026

Keywords: Source Separation, Source Grouping, Recycling, Municipal Refuse Disposal Measurement, Motivation, Containers, Collection Vehicles, Separation Plants, Organisation, Economics, Cost Benefit

SOURCE GROUPING TECHNOLOGY

An Introduction to a Household Waste Recycling Technology

Per EO Berg

PUBLIKATION 3:85

LICENTIATUPPSATS

PREFACE

This report is my licenciate thesis at the Department of Sanitary Engineering at Chalmers University of Technology. It is also the first report in English assembling the major findings made by the Residual Research Recycling Group at Chalmers. The group was founded in 1977 to do interdisciplinary research on solid waste. During its first years Avfallsgruppen contained five persons representing the following disciplines: technolgy, sociology, economics, ecology and philosophy of science.

Today (in January 1985) the following persons are members of the group:

Marie Arehag,	hygiene and ecology (since 1982)
Per EO Berg,	technology
Torsten Hultin,	sociology
Bo Segerberg,	engineer (since 1979)

A sincerely greatful acknowledgement to the members of the group for jointly shared interdisciplinary research, to the Swedish Council for Building Research for financing the investigations, to Inger Hessel and Monica Vargman, who typed the manuscript, again to Bo Segerberg who has supplied me with data and drawings and to Professor Peter Balmér for advice during the final part of my work.

Finally I want to thank my friend Linda Schenck, who has contributed in many ways: discussing, listening, criticising and, more over, helping me for countless hours with my English.

SUMMARY

This thesis is intended to provide the reader with an introduction to source grouping technology and techniques. It assembles the major findings made by the Residual Recycling Research Group at Chalmers University of Technology. The thesis deals with household waste only.

The technology applied in plants for mechanical separation of waste is seen as an addition to the traditional getting-rid-of-waste technology. Today´s mechanical separation, carried out in large separation plants is founded on, and includes, one or sometimes several steps of conscious mixing. An alternative to mechanical separation is known as "source separation technology", which means that mixing is consciously avoided, and materials initially grouped. Consequently the technology is now most appropriately called "source grouping technology". It is discussed on the basis of today's waste handling and two recycling tests made by the research group.

Large amounts of waste are a logical conclusion of urban living. In the past, the most important types were animal dung, latrine waste garbage and ashes. Today, the composition of household waste is increasingly complex. A historical need for a "getting-rid-of mentality" is defined and combined with an actual financial need for this consciousness or mentality.

Today the situation is changing. We can see an "objective" need for new sources of raw materials although the national welfare and profits are still based on wasting.

Swedish household waste, as measured in various municipalities is found to be a mixture of different materials. It consists of 40-50 % compostables, about 30 % miscellaneous dry recyclables and 10-25 % miscellaneous combustibles, the rest being various nonrecyclable and noncombustable materials. One-family houses generate more solid waste per capita than apartment houses. The range of values is wide, from 6 to 13 kg of waste per household and week.

The last 10-15 years have provided the public with a new and higher consciousness of environmental protection and materials saving. Our waste treatment must be based on two new factors: environmental protection and recycling of material in order to reduce raw materials consumption.

Every individual´s waste consciousness is moulded from information and actions. These dimensions can develop into a recycling consciousness by introduction of both information corrsponding to a new awareness, and opportunities to put that awareness into action.

People who are introduced to a source grouping system will easily accept the new materials handling system and become involved in recycling activities. It proves to be more problematical to discontinue a source grouping test than to introduce it.

On the basis of the experience gained from the two tests carried out by the research group, a method for giving people motivation is presented.

There are two main justifications for source grouping: recycling and pollution control. The basis for the choice of materials for recycling is described as related to the collection technique used, the degree of ease in handling, the market prices and the available quantity of each material.

The most important difference between waste collection and recycling may be that waste has to be collected close to the source. Recyclables, on the other hand, can be collected either close to the source or at recycling centers, each of which can serve thousands of households. This thesis concentrates on the source-directed systems.

The thesis then describes a pilot source grouping test in Gothenburg and a full-scale source-directed grouping system tested in three municipalities in southern Sweden. The system, which has been tested since 1981, has full collection and transportation, storage and preparation systems, using a four-chamber collection vehicle and specially developed reusable plastic sacks.

It was found that about 75 % of the available paper, 50 % of glass, textiles and compostables and 20 % of metals could be collected separately.

Recyclable paper is found to consist to 65-75 % of newsprint. Glass in waste is found to be 70 % white and 30 % colored, while recycled glass is almost fifty-fifty. Metals in household waste today are found to be about 45 % aluminum and 55 % ferrous metals, while recycled metals are only about 11 % aluminum.

The most effective organization appears to be a mixed one, with the municipality as the head and one or more contractors as executors. The economy of source grouping techniques is then discussed on the basis of the full scale test. It is found that this particular system today is expensive if costs and benefits are calculated in terms of the recycling system in isolation. However, 80 % of the losses are incurred in collection in rural areas. The losses can be distributed back to the costs of household waste disposal. This distribution shows that the total cost for residual disposal (recycling and landfilling) is not more than incineration in a waste-to-energy plant.

Like the thesis as whole, the discussion and conclusion sections make no claim to general applicability. However, it is stated that source grouping technology provides a good basis for the creation of recycling systems for dry materials. It is also stated that more research has to be done, especially on recycling compostables by source grouping.

1. INTRODUCTION

1.1 Point of depature

This thesis assembles some of the most important findings made by The Residual Recycling Research Group, henceforth referred to as "Avfalls-gruppen", at Chalmers University of Technology.

The thesis is also intended to provide the reader with an introduction to source separation technology and techniques. The details of our research and the models are available in Swedish as reports /1, 2, 3, 4, 5/ from the group. The following is a presentation of the basic ideas behind and the technological foundation for a materials handling system that then has to be adapted to local conditions.

Today waste handling is mostly a method for getting rid of various un-acceptable materials. These materials are all handled in the same way irrespective of their specific characteristics. There is only one thing that determines the way of handling and the method of disposal: the source.

Since this thesis is only about household waste, I will exclude all other kinds of waste from my discussion.

I refer to the generally accepted waste disposal paradigm as the "getting-rid-of-paradigm" of waste disposal, and contrast it with conciousness raising on environmental protection and resource conservation issues. The group has used consideration for resources, on an ecological basis, as its point of departure and has based its position on values, such as:

1. Preference for simple techniques and technology.

2. Preference for ecological (i.e. energy and resource saving) handling.

3. Giving priority to methods that affect the users.

4. Making financial determinations from the point of view of the national economy.

Working interdisciplinarily means that we constantly find ourselves in the borderland between different scientific environments, cooperating in investigations made in unfamilar disciplines and communicating with people whose experience is different from our own. In this thesis I present my interpretation as an engineer of the accumulated results of the group. However, after seven years in the group, I am an engineer with special experience and - possibly - a somewhat unusual idea of the universe.

1.2 On interdisciplinary research

There is no single satisfactory method for interdisciplinary reserach. The group has used an interdisciplinary collocation of results from disciplinary subinvestigations, and jointly generated data. This means that the individual scientist has the responsibility for his or her sector of the investigation, and the other members of the group have to trust his or her abilities. Under these circumstances it is possible to use methods peculiar to each specific discipline, without conflicts arising between the members of the group as regards validity or reliability of data.

In this step it is very important that the members of the group participate in one another's subinvestigations. Such work creates a special kind of understanding - over the borderlines within disciplines, thus facilitating the next step - the interdisciplinary collocation.

The particular methods practiced by the individual disciplines are reported on in references 2 and 5.

In a previous report /2/ I have described our interdisciplinary collocation as "hermeneutic". I mean that all collocations are made on the basis of "prior understanding". This prior understanding is a result of the individuals' experiences, formed both throughout their lives and under those special conditions we call research. If the individual has some experience from "unfamilar" disciplines, this contributes to his or her prior understanding, in a way which makes it easier for colleagues to cooperate.

The collective interdisciplinary collocation of the disciplinary results with the jointly generated data is a difficult step. To understand a worldview which is totally encompassed by another person, but not by oneself, is nearly impossible. Martin Heidegger /11/ states that our understanding is dependent on our world, just as our world depends on our understanding. Consequently, the interdisciplinary collocation requires the individual scientist to rise above that world (or part of the world) that is defined by his or her daily disciplinary research.

1.3 Terminology

I define the word "technology" as meaning the doctrine of techniques, a scientific discipline. Techniques are the construction and use of artifacts. I place technology in the field of the social sciences - not in the field of the natural sciences as many other engineers do. This opens a new world of theories constructed on the basis of philosophy, that may help me to explain what techniques are and how they serve society.

A language includes many words which describe one and the same phenomenon, but often every single word also carries a special value added to the description of the phenomenon. In this field English is a rich language, and a difficult one too, because it has also developed in different ways in different parts of the world. I have tried to use American English, but I know that there are also traces of British English in my thesis. It is, however, important for me to give a few of the main words special and well defined interpretations. Thus a brief glossary with help from reference 23:

Residual product, residue

Material left over in (production) processes or consumption; c.f. Recyclables, waste/refuse/garbage, pollutant. R. has neither positive nor negative connotations.

Recyclable

Residue saved for recovery; c.f. waste/refuse/garbage, pollutant. R. can arise directly from production or consumption or in connection with waste treatment. R. can be subdivided into reusable products, e.g. returnable containers and secondary raw material, for example, recyclable metal or discarded tires used for road surfacing. R. carries positive connotations.

Pollutant

A substance, usually a residue, which is so dispered throughout another substance or system that it suffers an undesirable deterioration in usefulness.

Waste/refuse/garbage

Discarded residue to be disposed of and dispensed with, for which reason it is considered of negative value. Waste, refuse and garbage are given the same values and can, consequently, be used synonymously.

Compostables

Organic residue, for example, kitchen residue, diapers and wet paper. C. have the value of residue from consumption and can either be wasted or recycled.

Recycling

The removal of valuable materials from our residues before they become part of the waste stream, the separate handling of these materials and their recovery.

Recovery

The use of recycled materials in production processes.

Separation plant

Waste treatment plant, where the waste is mechanically separeted into different fractions. S. is often connected to a composting plant or a waste-to-energy plant.

Selection analysis

Analysis of mixtures in order to determine their composition. SA of waste consists of manual selection and classification of every item and then grouping into classes, i.e.: paper, compostables, glass, hazardous materials, etc. The weight, and sometimes also the volume, of every class is registered.

2. BACKGROUND

2.1 Municipal Refuse Disposal

In Sweden - as in most industrialized countries - household waste is collected as a mixture of materials, on the basis of hygienic/sanitary interests. Individuals mix their waste in the kitchen - in Sweden normally in plasic bags. The plastic bags are then carried to the garbage chute or to the refuse bin/sack, which is brought to a collection vehicle by the garbage man. In the vehicle, the refuse sack is mixed with other sacks, and sometimes also with more or less unpacked waste from refuse bins.

Normally the waste is compressed in the vehicle, which means that moisture and salts migrate from wasted food to other - dry - absorbant materials such as paper and different kinds of composites. The vehicle transports the waste to a landfill, a waste-to-energy plant or a separation/composting plant. At the landfill the waste is disposed of "forever", and in the waste-to-energy plant it is incinerated, energy and ashes being produced as the benefit of this destruction.

Ideally the benefit of separation plants would be pure separated materials. In reality, however, the separated materials are still too polluted with different kinds of junk that has joined the materials during the waste handling process. This situation is the only logical result of a separation processes that begins with mixing.

The processes used in the waste separation plants are all derived from other kinds of management not related to waste, but to production. The separation processes require materials that are unpackaged, free from plastic bags and garbage sacks, and often also cut into pieces. Therefore the waste has to be shredded as the first step of of the separation process. Most shredding is hammer-mill shredding. During the shredding process the waste is irretrievably mixed.

The obvious conclusion is that a mechanical separation system is always based on - and includes - one or perhaps several steps of conscious mixing. Thus we have to ask: Why do we prepare for separation by mixing?

Shouldn't we go the other way, and avoid mixing when preparing for separation? This should be the eventual technological basis for all kinds of separation and recycling.

2.2 Source separation technology

There is just one alternative to mechanical separation: source separation - source grouping. This is a system that avoids mixing of materials that are not already mixed. Consequently source separation technology is not really separation technology. Rather, it is the doctrine of techniques for keeping things apart. This means, in a society where we are all socialized to throw all our waste into one mixture, that source separation technology demands human involvement. The techniques created have to be well designed man/machine systems, where all artifacts are developed to serve man, as opposed to many other contexts today, where man often is subordinated to machines.

Source separation has long been practiced, but has been studied very little. In recent years some experiments have been made and reported on. One of the most important and thorough existing studies was made in Konstantz, West Germany, where a source separation test was investigated by members of various scientific disciplines /16/. Other experiments have been made elsewhere, but since source separation always involves a social environment, results are difficult to compare.

Today, source separation is considered problematical, because it requires involvement from individuals. Too many people have been believed to reject personal involvement in such a recycling system. Although source separation has traditionally been technically successful, it has long been believed that personal involvement was difficult to obtain. Yet collected materials have held high quality and some materials have also been collected in large amounts too. However, the financial side of recycling has been problematical for a number of years.

2.3 Hypothesis

On the basis of the background given above, I am prepared to establish some hypotheses for the investigation of the source separation man/machine system: today's joint waste stream appears unsatisfactory, the viable alternative being separate material streams. This requires personal (individual) participation and simple techniques. In addition, it has to be financially feasible.

1. It is possible to base recycling on source separation, i.e., on common peoples' willingness to be actors in a recycling system.

2. Source separation can be managed with modification of well known techniques.

3. Source separation is financially feasible.

2.4 Two investigations

This report is based on the experience from two experiments with source separation: the Bagaregården test - a pilot test - and the Nårab Region Recycling System - a full scale test. Both were carried out in Sweden by Avfallsgruppen.

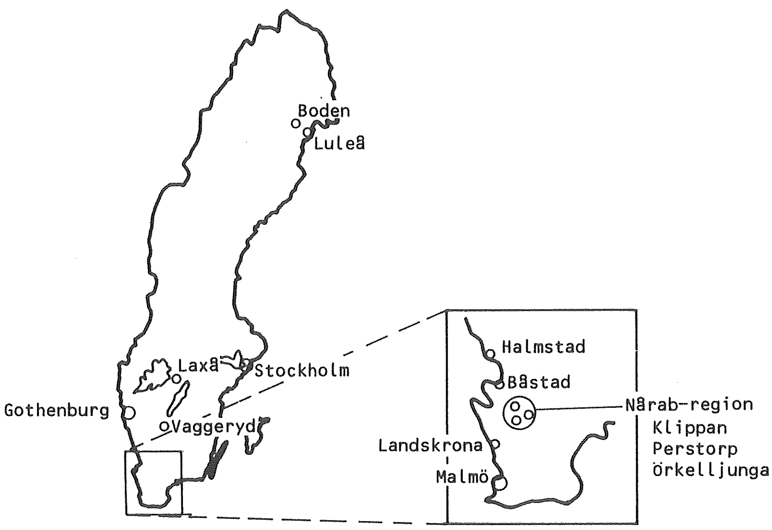

Figure 2.1

2.4.1 The Bagaregården Pilot Test

The Bagaregården tests began in February 1979, after one and one half years of planning. The test covered 112 households in two blocks of apartment houses in the district of Bagaregården in Gothenburg. Paper, compostables (food and other organic material), glass and metals were the items separated. The paper was collected using the ordinary paper collection system, while the compostable materials and a mixture of glass and metals were collected by temporary arrangements for collection and transportation. The rest - the remaining waste - was collected and handled via the ordinary waste handling system.

The buildings had no garbage chutes, but large ordinary refuse storage rooms, where the separated materials were stored in ordinary refuse bins, which were marked "paper", "compost" and "glass and metals".

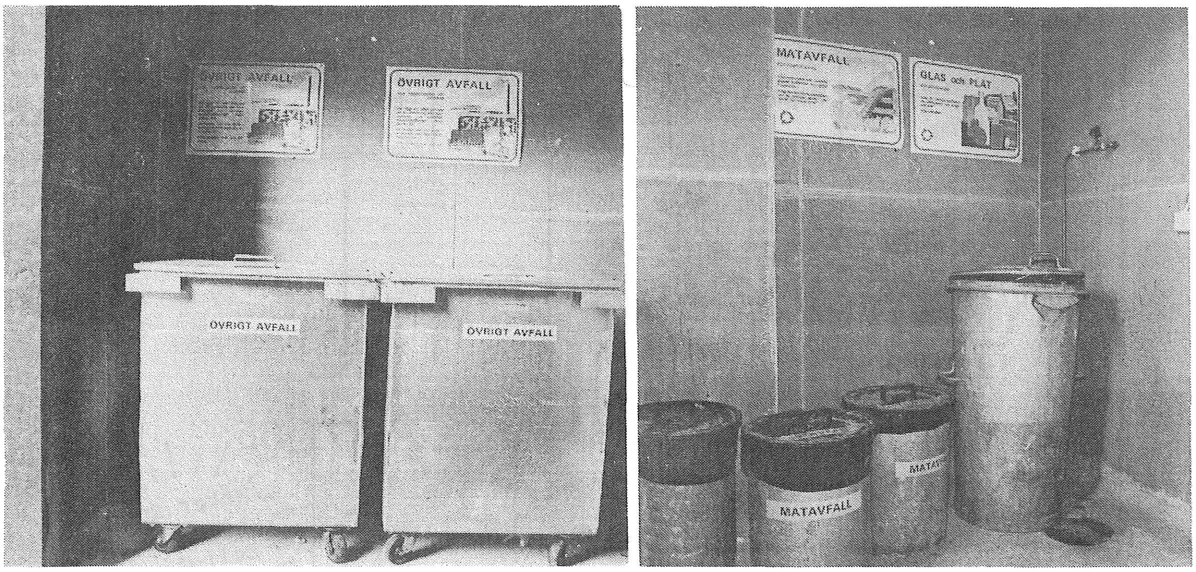

Figure 2.2 Refuse storage room in Bagaregården during the source separation tests.

The test came into being on the basis of both the inhabitants of the Bagaregården area's explicit willingness to be involved in the new materials handling system and Avfallsgruppen's promise that all the separated materials would be recycled.

Avfallsgruppen followed the test for the entire three and one half years of its duration. The research group measured collected quantities of separated materials and their quality, as well as the peoples' motivation for and attitudes towards the new materials handling system.

This test is reported on in Swedish in references 1,2,3,4 and in English in reference 6.

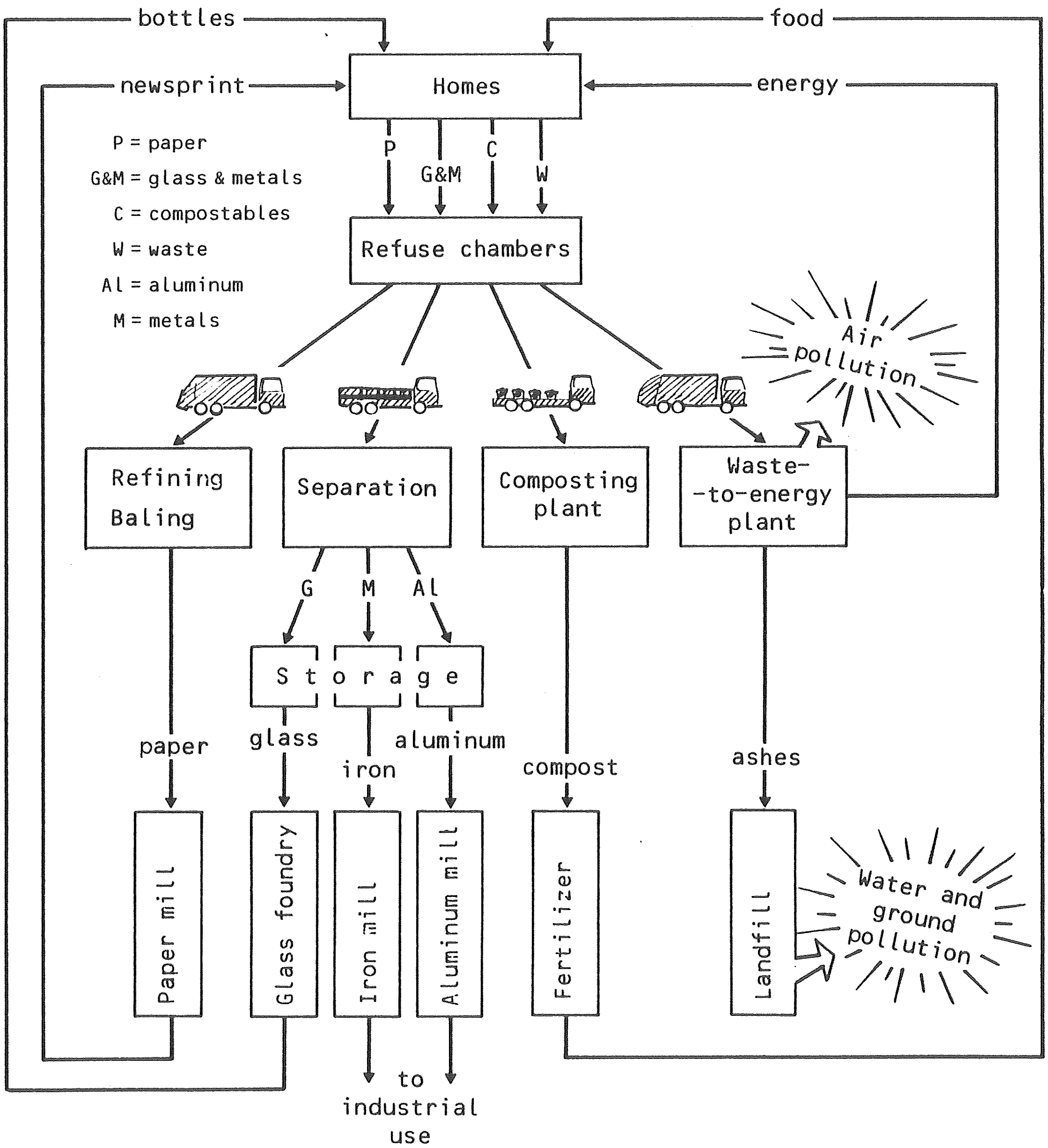

Figure 2.3 Flow chart of the Bagaregården pilot source separation system.

2.4.2 The Nårab Full Scale Test

The Nårab Region Recycling System is the first full-scale test of an advanced source separation system to be realized in Sweden. The Nårab recycling system began in August 1981 after one year of pilot tests in the municipality of Klippan, and is still ongoing. Paper, glass, metals and textiles are collected separately from the one-family houses in the villages and the rural areas. Only paper is collected separately from the apartment houses. Some pilot tests on glass separation are being run, and an adaption of the apartment houses to the source separation system has now begun.

The Nårab region, which includes the municipalities of Klippan, Perstorp and Örkelljunga in southern Sweden, contains 13,600 households (33,000 inhabitants). Of these households 4,600 are in apartment houses, 6,000 are in one-family houses in the various villages and 3,000 are in rural areas.

The three municipalities share one corporately-organized sanitation company - Nårab - which has a contractor, "Skånemiljö", responsible for the waste collection and transportation. Skånemiljö has also been responsible for paper recycling since 1978.

The separated materials are collected in specially designed, returnable plastic sacks, which are emptied into a specially designed four-chamber vehicle. The individual households see to it that their sacks are placed at the edge of their property, where the "recycling man" collects them, empties them into the vehicle, and then returns the empty sacks. The collected materials are stored at Hyllstofta Landfill Site until they are delivered to purchasers.

This investigation is reported on in reference 6. The main research report in Swedish /5/ was published in December 1984.

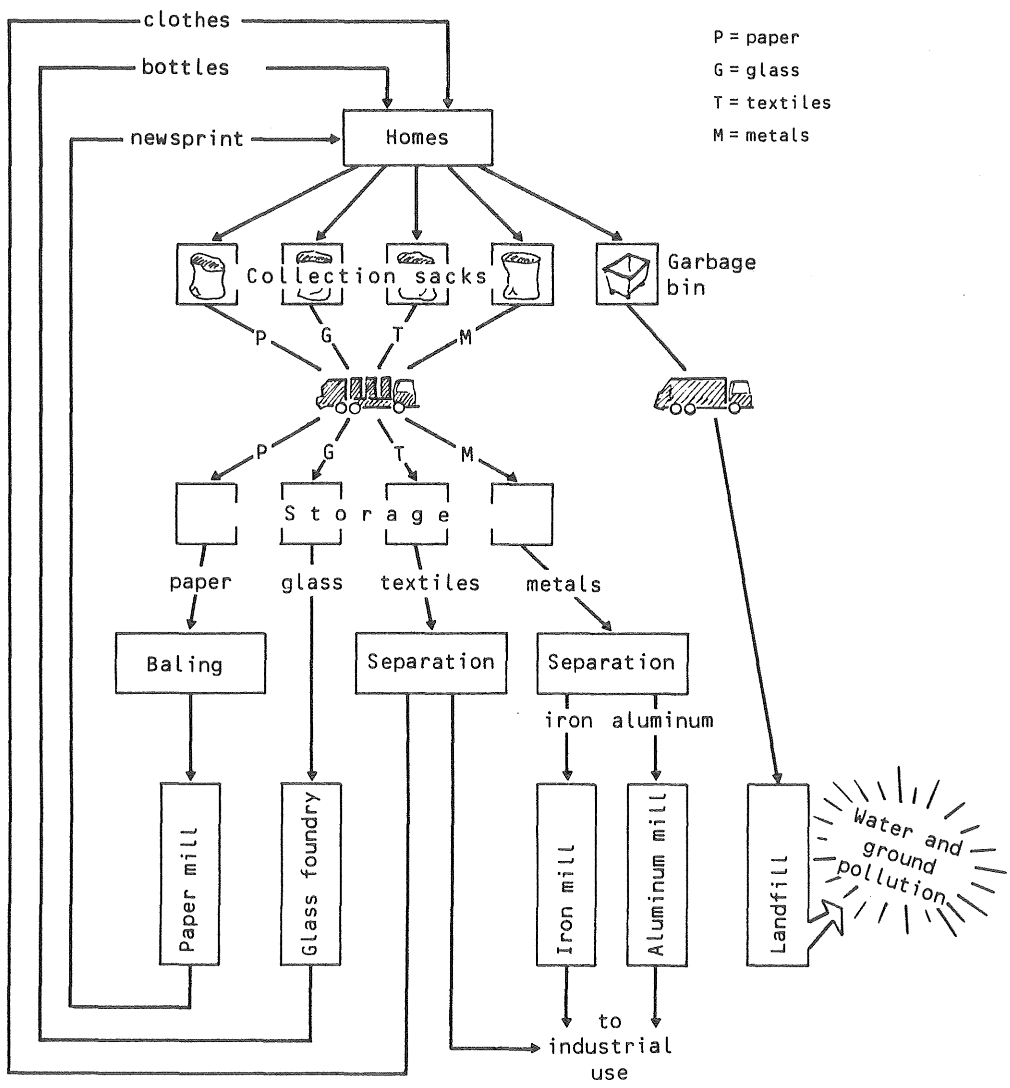

Figure 2.4 Flow chart of the Nårab source separation system.

3. THE HOUSEHOLD WASTE STREAM

3.1 General comments on making measurements of the waste stream

Household residuals are generally separated into a wet waste stream and a solid one. The wet stream contains toilet residuals and water used in the homes. The solid stream contains kitchen residue, newspapers and all other kinds of solid residuals found in a home or a refuse sack and is usually referred to as household solid waste. In addition, there is another solid waste stream containing larger items, such as old furniture, bicycles and so on.

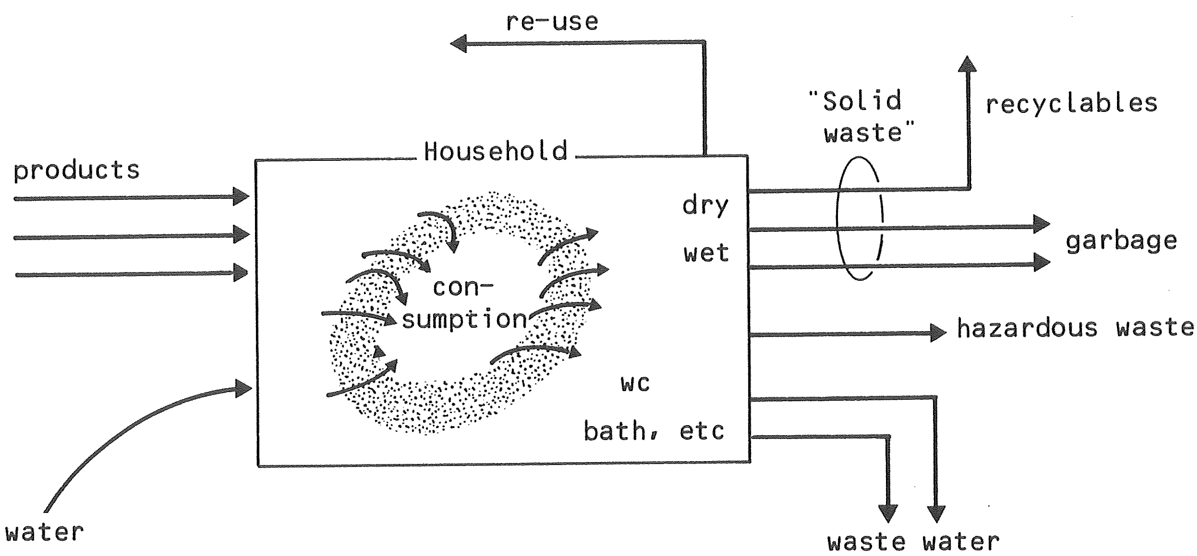

Figure 3.1 Materials stream through the household.

In Sweden household waste and waste from different activities (offices, public helth centers, etc.) and businesses (shops, etc.) are generally collected in the same vehicles and on the same undifferentiated collection routes. Thus it may be hard to tell if a given study reports waste collected from households or general waste collected as "household waste". These interpretation problems create difficulties in the comparison between our data and that of others.

This interpretation difficulty is also rooted in the different methods of data collection used by different investigators. All data quoted here comes from data collection close to the source, i.e. the investigated waste has been collected from selected houses on the same day the regular collection was made, and was analysed within three days. Problems in measuring the solid waste streams were discussed at a seminar in Aalborg, Denmark in April 1983 /17/, and later in Northampton, England in September 1983 /19/. There is also some literature given on this problem /8,13,18/.

The most important interpretation problems are:

1. Lack of standard components in the selection analyses.

2. Lack of standard method of stratification of background data.

3. Lack of objective knowledge about how much waste we need for accurate analysis.

Figure 3.2 Selection analysis in Klippan 1982.

Household waste in Sweden has been analysed in the light of all these sources of error in the data, and on the basis of amount of recyclable paper, compostable material (food, etc.), plastics, textiles, other combustible materials, glass, metals and other noncombustible materials. Results from five investigations made on waste collected at the source are shown in Table 3.1.

Table 3.1. Composition of household residue in six Swedish municipalities (by % of weight).

Materials analysed		Gothenburg Bagaregården 1980	Luleå* 1981	Boden* 1982	Nårab 1983
Paper		31%	12.3%	11.0%	20.5%
Compostables		41%	45.2%	43.5%	56.5%
Glass		8%	7.6%	7.5%	3.9%
Metals		3%	3.3%	3.5%	2.5%
Textiles		4%	0.2%	1.5%	1.0%
Plastics		3%	4.2%	7.1%	4.2%
Misc	combustibles	11%	24.3%	22.6%	10.6%
	noncombustibles		2.3%	3.3%	4.2%
Total amount (kg/hh & week)					
per household	one-f. h.	-	11.3	11.1	13.1
	apartm.h.	8.6	7.3	5.9	6.5

Bagaregården: All residue; 6 selection analyses; 52 weeks

Luleå: 2 test samples from 6 areas during the winter

Boden: 2 test samples from 6 areas during the summer and autumn

Nårab: 2 random sample tests each of 2 weeks' waste and 2 months' recyclables; September and January/February.

* The two investigations in Luleå and Boden were made with the involvement of Avfallsgruppen and are reported in detail in references /7/ and /10/. In neither Luleå nor Boden is the paper disposed of in the separate paper collection system included in the waste volumes. This loss is in the range of 1.0-1.5 kg/hh & w.

In the Nårab-region, in Luleå and in Boden the waste sacks are stratified as to different types of dwellings. As illustrated in the data from Boden and Klippan in figures 3.1 and 3.2, one-family houses generate more solid waste per capita than apartment houses.

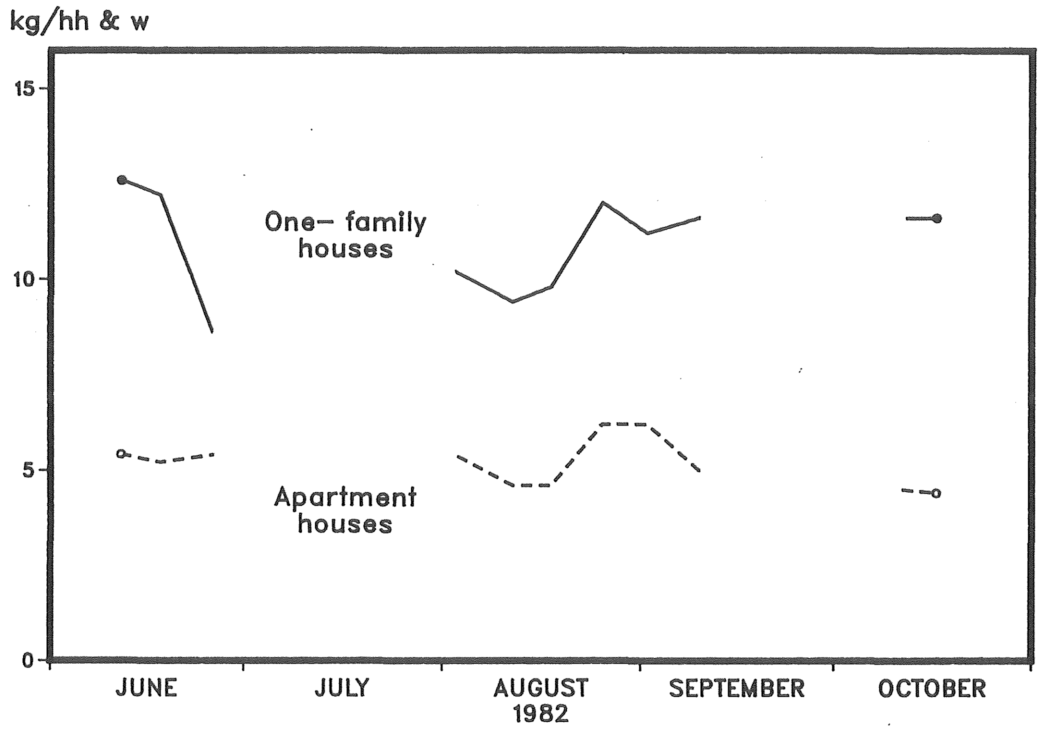

Figure 3.3 Waste generated in Boden, 1982. /7/.

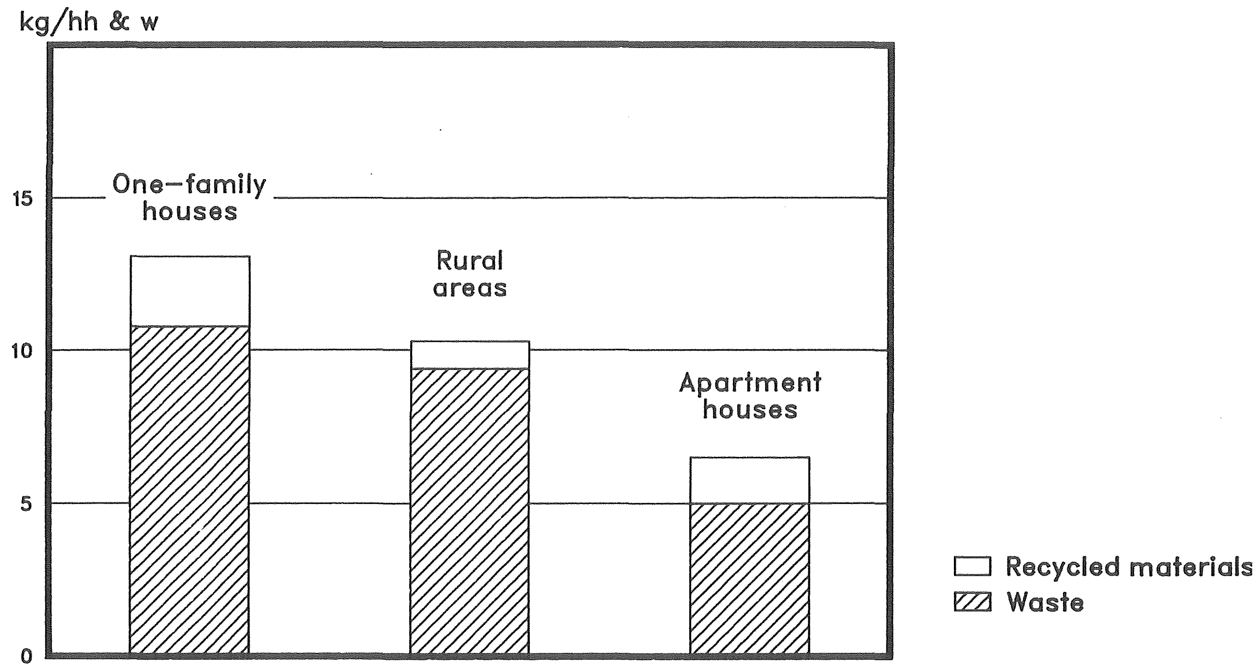

Figure 3.4 Residue generated in Nårab region, 1983.

The range of values is wide, as is illustrated in the data from Luleå, where the households were stratified first as to type of dwelling and then as to income and other socioeconomic background data, see Figure 3.5.

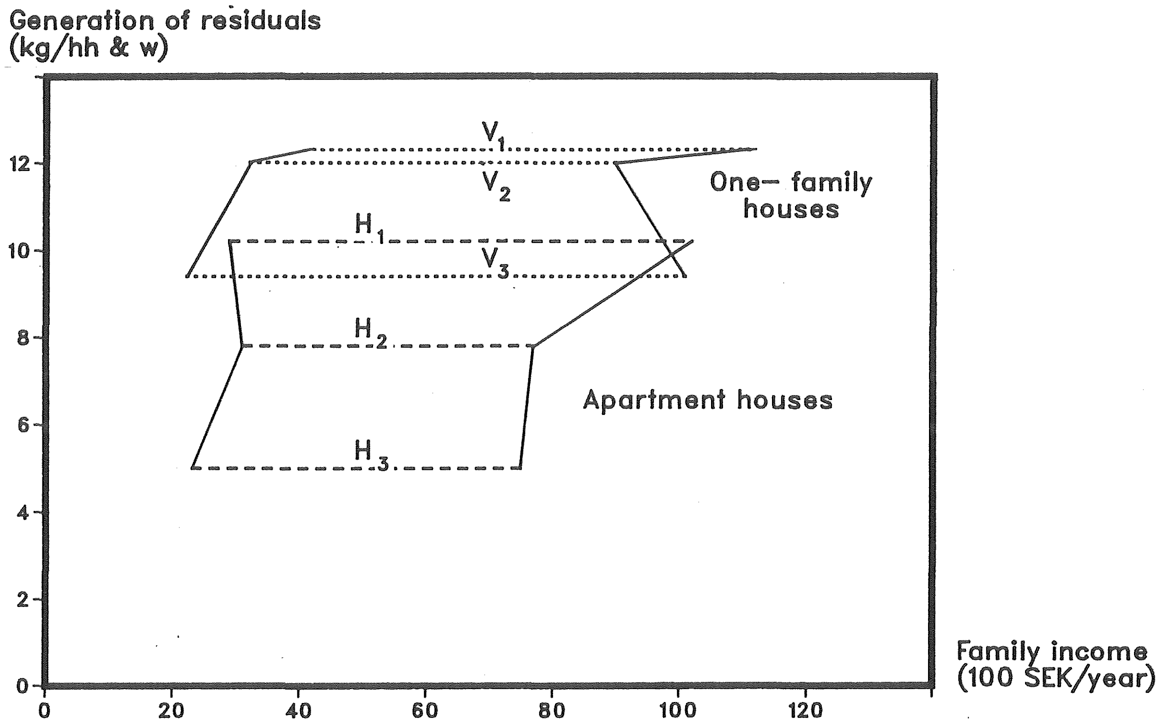

Figure 3.5 Waste generated in Luleå, 1981. Waste quantities in selected areas, stratified as to socioeconomic variables. V1 - V3 areas with one-family houses. H1 - H3 areas with apartment houses. /10/.

The different materials are analysed in selection-analyses with reference to species of particles. By examining a sufficient number of waste sacks you can get a good mean value for a defined population. That number is hard to set. Avfallsgruppen has used 1% of the total waste-flow - collected as a sample test in the Nårab region. In the Bagaregården tests the total flow was generally analysed. In Bagaregården selection analyses were carried out six times the first year and three times the last 2.5 years. In the Nårab region two selection analyses were made in two years.

3.2 Composition and quality of recyclables

The compostable fraction in waste is similar regardless of the type of dwelling and part of the country. Depending on the age of the children, there is a difference in the quantity of diapers. There are also seasonal modifications, such as a lot of fruit-peels and berry residue in September, an increase in orange peels in February, etc.

The paper fraction in household waste consists of different kinds of paper, all of which are recyclable, see table 3.2. Nonrecyclable paper is classified as compostables or combustibles. The recyclable paper fraction is constant across the seasonal variations. There are, however, geographical modifications related to the size of the regional daily newspaper. See Table 3.3.

Table 3.2 Composition of separately collected paper.

Species	Bagaregården	Nårab
Newspapers	64-75 %	67.2 %
Magazines	9 %	16.0 %
Advertisment	9 %	n.v.
Wrappings	4-6 %	n.v.
Corrugated paper	0-12 %	2.3 %
Other	ca 1 %	14.2 %
Impurities	0 %	0.3 %

Table 3.3 Newspaper circulation by weight in relation to amount of paper in residuals. /3,5,24,27/.

	Year	Wasted paper kg/year	Recovered paper kg/year	Morning newspaper circulation ex/100hh	Morning newspaper weight kg/year
Bagaregården	1980	150	119	88	62
Luleå	1981	127	57	98	38
Nårab	1983	108	78	92	55

The quantity of recycled paper fluctuates during the year. In Bagaregården and in the Nårab region we found a peak in August - September, which seems to illustrate that people generally dispose of large quantities of paper after their four weeks' holiday, see Figure 3.6. The peak also counterbalances a decrease in recycled paper during the summer, when a lot of people are out of town.

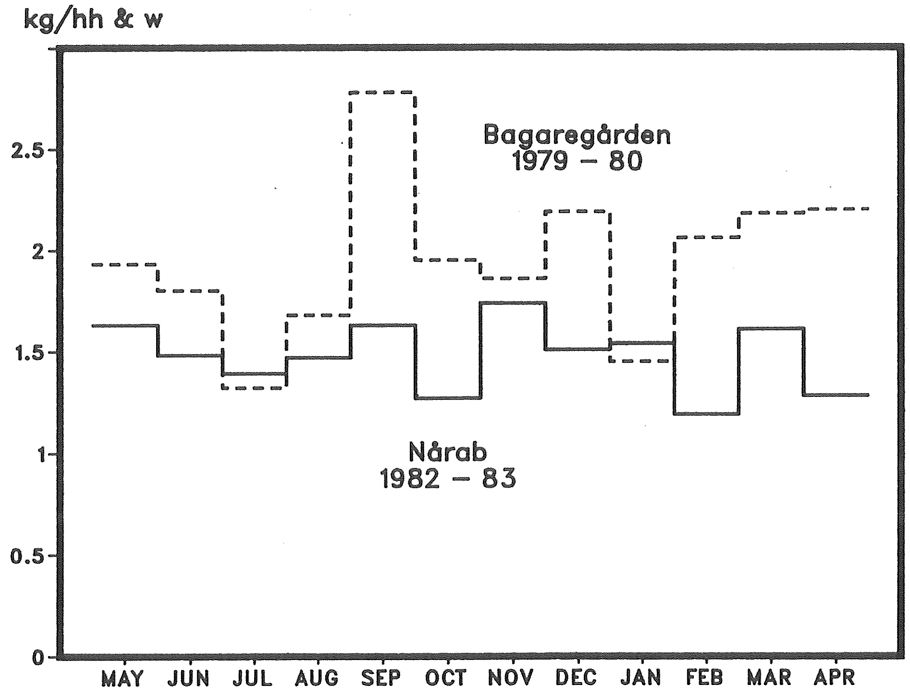

Figure 3.6 Seasonal variations of recycled paper.

Glass consists of jars, bottles and a small amount of decorative glass. The Luleå data from 1981 shows that about 75% of all the glass in ordinary waste is transparent white, and 25% is colored. Hovsenius reported 78% white and 22% colored glass in Laxå in 1975. /12/ In Bagaregården in 1980 and in the Nårab region in 1982 glass separated at the source was analysed and found to be about 50% white and about 50% colored glass. The differences depend on different analysis situations. Glass collection systems reject glass that is very dirty or contains food residue, etc. This glass is generally wasted.

Table 3.4 Distribution of white and colored glass in household waste.

	Year	White	Green	Brown	% Of total amount
Laxå	1975	78%	22%*		3.3 %
Luleå	1981	70%	20%	10%	7.6 %
Bagaregården**	1979	55%	33%	12%	8 %
Nårab**	1982	45%	38%	17%	3.9 %

* colored glass, green + brown

** source separated glass

The glass analysed in Bagaregården consisted of 40% non-deposit liquor bottles. The rest was glass jars, juice and soft drink bottles and deposit bottles of different kinds. Probably more deposit bottles were put in the bottle bins, but were removed and sold before the collection.

Table 3.5 Composition of glass fraction in household waste, Luleå 1981 /10/.

Wine and liquor bottles*	49%
Other bottles	20%
Jars	22%
Packages for pharmacenticals	2%
Misc. glass	7%

* of these every second bottle was a deposit bottle

Metals consists of cans and small numbers of other objects (knives, gadgets, tools, etc.). In recent years the number of aluminum cans has increased widely, and consequently the metal fraction is no longer homogenously ferrous.

Table 3.6 Composition of metal cans in household waste.

	Bagaregården to May 81		Bagaregården from June 81*		Nårab		Luleå 1982		
	weight of sample		weight of sample		weight of sample		number	weight of sample	
Al-cans	69 kg	6%	21 kg	11%	0.9 kg	11%	1035	21.7 kg	45%
Fe-cans	1008 kg	94%	172 kg	89%	7.3 kg	89%	494	26.9 kg	55%
of Fe-cans above, imported							272		

* Aluminium cans were introduced on the Swedish market 1 June 1981

There is an important difference between the analysis of metals from Bagaregården and Nårab and the analyses of metals from Luleå. The first two analyses were made on source separated metals, while the third was made on metals found in mixed waste. This table shows the importance of measuring near the source and, what is more, the importance of giving the year and of using the waste stream as well as the stream of recyclables when measuring or calculating the residual stream from the households.

4. MAN AND HIS RESIDUALS

4.1 The wasting paradigm

When the first towns were built, man's activities were split into professions. A new way of handling materials had to be developed. A town could not survive without products from the neighborhood and from other towns. Neither could it survive without exporting products to other towns and to the outlying area. The town drew raw materials and products to it,and this consumption resulted in production of residuals. While many of these residuals were used, others had no usable value and were wasted.

Urban living itself produced a lot of household waste. The most important types were animal dung, latrine waste, garbage and ashes. The organic materials were a source of odors and other sanitary problems in the towns. Soon so much organic material had been dumped in the streets and in the courtyards, that the waste had to be transported out of town. Sometimes towns were buried under their own waste. In London, there are streets with surfaces 6 meters above the original level of the Roman City. /21/. We can also read of the Parish Church of St. Katherine Christchurch:

> "This church, seemeth to be verie olde, since the building whereof the high streete hath beene so often raised by pavements that now men are faine to descend into the said Church by diverse steps seven in number."

The early urban solid waste problems can be described as "small towns - small problems, big towns - big problems". Swedish towns, including the capital, have always been relatively small, and the waste problems seem to have been comparatively small as well, but the general sanitary problem was a matter of fact. In 14th century Stockholm there was a kind of public sanitation department with only one duty - to get rid of the nasty smelling garbage. It was first dumped into the water surrounding the town and later disposed of on land outside the town./9, 26/.

We can define the early urban waste problem as a sanitary one, with an abundance of materials with no usable value.

It was important to the burghers and their life style to have a method of getting rid of their useless materials and their waste. This feeling has survived today as well, as became obvious in the strong feelings aroused during the sanitation workers´strikes in Europe and the USA in the 1960's and 70's.

In the modern industrialized community, products must be wasted as a reality of the economy. Expanding markets in the industrialized and capitalist world are founded on waste. The faster the rate of wasting is, the faster the need for new products develops, and consequently the higher the profits and the more work. We can define a historical need for a "getting-rid-of mentality" combined with an actual financial need for this consciousness or mentality.

This mentality is encouraged by the modern "communication society". We consume a lot of paper as newsprint, a logical consequence of our need for information. This newsprint also contains a lot of advertising: 40% of the text space is often used for advertising in major newspapers.

The increase in packaging is often said to be a consequence of the "distribution revolution" which materialized as a boom in supermarkets during the 1950's and 1960's. As a matter of fact, the increase in the use of disposable packaging was also a part of the process of socialization leading to a consumption-disposal mentality.

This collective mentality is an inherent part of every individual´s personality. It is the foundation on which we build our daily lives. We are given no choice of action and so we remain true to this "wasting paradigm".

Looking at waste handling technology, we find that it is constructed on the same foundation - landfilling, incineration and conversion. (Conversion is the only true result of mechanical separation and large scale composting).

We can still find that nearly every sanitation department acts in the direction of materials destruction, on the basis of the need to get rid of the hygienically problematical materials in densly-populated areas.

Today the situation is changing. We consume so many materials at such a fast rate that we can see a need for new sources of raw materials, although the national welfare and profits are still based on wasting. Waste also generates profits in the improductive sectors of society. Sanitation departments and private contractors make their profits from the transportation and treatment of waste. For these actors a reduction of the waste stream means a reduction of activity and, of course, of income.

This means that there are a lot of people with vested interests in waste and waste handling, all of whom make profits from the waste stream and for whom a reduction poses a real threat.

4.2 On the way to a new paradigm

The last 10 - 15 years have nourished the general public with a new and higher consciousness of environmental protection and materials saving. A new understanding has developed, that raw materials are scare and cannot last forever. Getting rid of waste is an ecological expense. Our waste management must be based on two new factors: environmental protection and recycling of materials in order to reduce raw materials consumption.

The traditional waste handling system can be described as a continuous flow of materials from nature - through society - back to nature, but it comes back in different concentrations, in unnatural mixtures and is dumped at places other than its original source. This model feeds pollution and encourages materials destruction.

A new waste treatment system must be founded on consideration for nature, for materials and for the work that is invested in every product. A general model of this concept can be described as a material cycle in society. This cycle - applied to reality - is naturally imperfect. There has to be some output or loss owing to small quantity consumption - and sometimes also to long-distance transportation of materials.

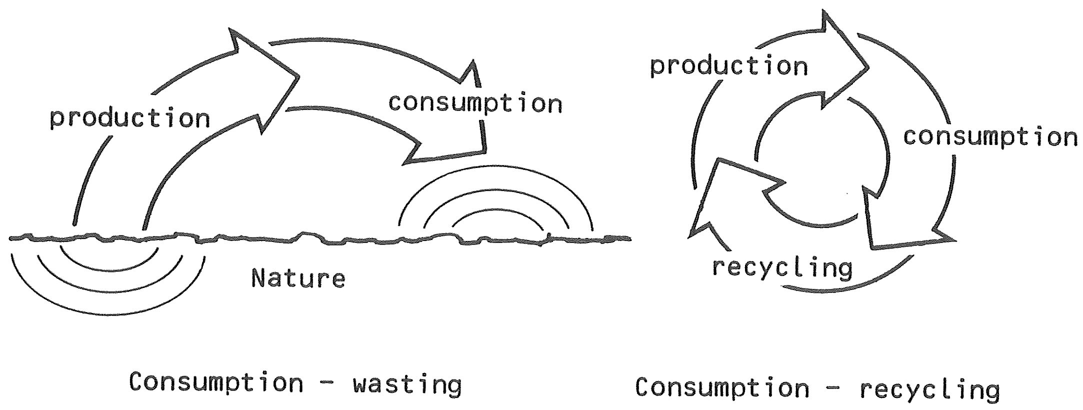

Figure 4.1 Two models for material handling.

Many ideas of how to realize the new model have been drafted and many plants have been built; 19 of then in Sweden. Heavy technology drafts of processes for central separation and composting were once thought of as the short cut to increased recycling. However, these heavy technology drafts developed out of the old paradigm. The first Swedish recycling/ composting plants were designed in order to eliminate sewage sludge /22/. Recycling became a method of getting rid of the waste with the separation plants as genuine parts of the old materials destruction system, rather than components in a recycling system.

However, the type of consideration mentioned above requires personal involvement in the whole materials handling system (including the recycling system). This position is impossible to reach from the "getting-rid-of-paradigm". We need a point of view where materials and products which have been removed from their original users are still considered to be of value as products or as materials.

4.3 Leaving the old position - reaching a new one

All our normal activities are results of an individual and/or collective consciousness. At the same time, every consciousness is moulded from the individual's activities and all kinds of information or propaganda that reach the individual. This can be illustrated as a triad, as in Figure 4.2.

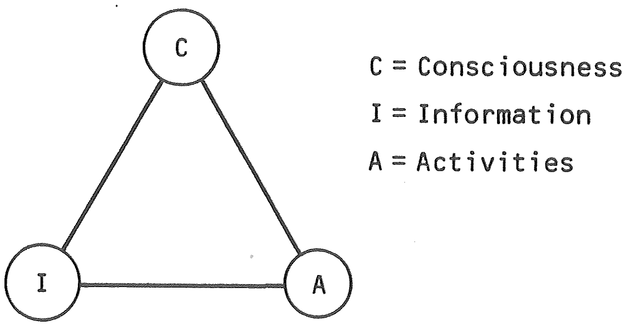

Figure 4.2 The triad of information, activities and consciousness.

Each individual´s private consciousness is basically built up of family upbringing and socialization. Every individual's waste or residual consciousness is contigent upon his possibilities to act. In Sweden there is generally only one possibility given - mix your household residuals and waste them together in the garbage chute or in the waste bin. There is - for more then 95% of the citizens - no other choice. All official information, propaganda and teaching are in line with this situation.

However, our society is pluralistic and in addition to the official regulations system and the public sanitation propaganda there is another stream of information relating to ecological facts, the scarity of materials and the social need for a private sense of responsibility for the future.

That information does not correspond with people's ability to act. Under given circumstances - at a seminar or over a bottle of wine with old friends - that information can contribute to consciousness raising, but with no practical implications, since these are precluded by the existing sanitation system. The higher consciousness has to be suspended in daily life.

When that higher consciousness gets a chance to correspond with daily actions, it will be formed into a solid personal position at the same time as the old sanitation consciousness will have to be suspended. Cutting off the possibilities for action in the old model and giving more information about the new model, can speed up the growth rate of the new consciousness.

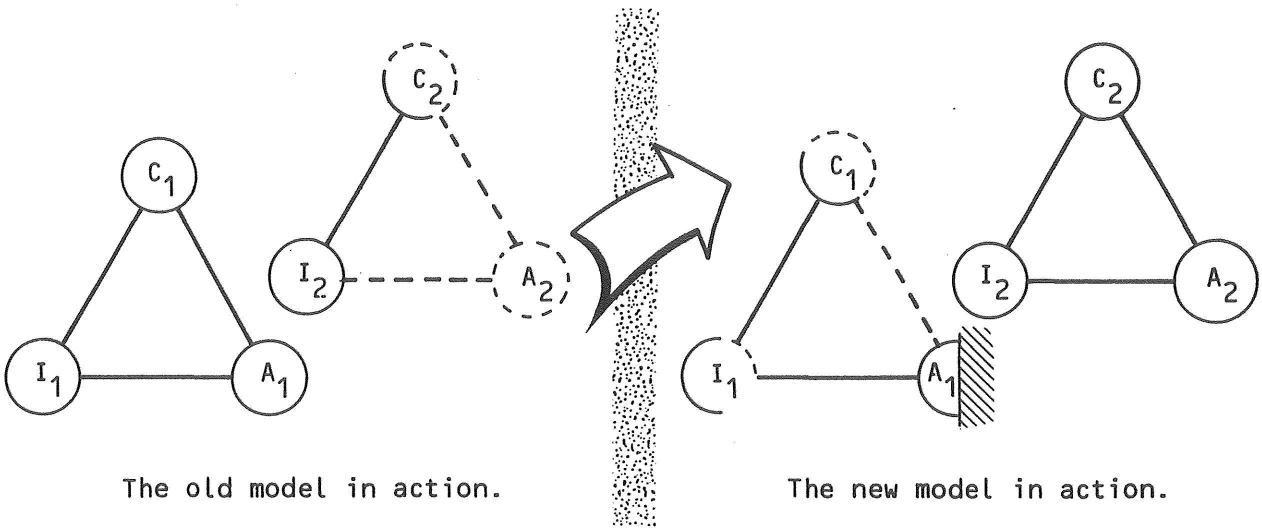

Figure 4.3 Steps toward a higher consciousness.

By introducing a new model of actions based on true information, it is possible to directly form a collective consciousness that implies a possibility of changing daily activities in a direction that facilitates the desired action.

4.4 Source grouping technology

Source separation technology is the doctrine of how to desist from mixing materials. It means adhering to the doctrine that materials that have not yet been mixed shall be kept separate everywhere (throughout the recycling process), and thus it is not really "separation", since there is no initial mixing.

Source separation is self-explanatory - keeping things apart. Who would choose to make the detour via a materials mixture when the materials are not yet mixed? The idea of source separation is not based on the premise that composite products are to be separated into recyclable and non-recyclable parts. In an extended sense, the production system has to be adapted to the residual treatment system, since production under this system never permits random materials mixing.

In practice, this means that individuals are informed about the need for recycling and presented with an opportunity to avoid mixing recyclables. It is important that participation be voluntary, because the participants' free will reflects the extent of consciousness raising. After some time -

perhaps a few years - the "new" handling system will have developed into the normal model and be "doing what comes naturally".

The term "source separation" is thus inconsistent with the reality presented above. Mixing residuals as waste changes to grouping them into recyclables and waste, and consequently the technology is now most appropriately called "source grouping technology".

Source grouping technology is easy to carry out because it corresponds with people's normal need for a life in which they are acting for positive environmental protection in their society.

A majority of a normal population will voluntarily associate themselves with a source grouping system, if they are only given good motivation and a useful system for the material handling. Such good motivation includes consideration for natural resources, economizing on raw materials and energy, and encouraging environmental protection.

A convenient system for materials handling is a service system that becomes part of an individual´s everyday life. Activities relating to the old waste handling system may be seen as being more complicated than those relating to the new system, and consequently people will find the new system more comfortable. /3,4,5/.

Source grouping is no master key. It must always be adapted to local circumstances. It is almost impossible to provide a detailed model of a source grouping system, rather it is the general postulates that are of interest, for individual adaption and application.

5. PEOPLE'S REACTIONS TO CHANGING WASTE HANDLING SYSTEMS

5.1 Participation: Definition and measurement

It is not easy to define participation, because every single individual has his or her point of view. For the individual in the household it is of great interest how often he or she desists from using the recycling system and puts a recyclable item into the waste, and, equally important, why he or she does so. It is not unusual that all beer and soft drink cans are put into the recycling sack, but dirty dog food cans, are put into the waste bin.

If you ask household members, in interviews or in a questionnaire, for their "degree of participation" they would probably answer: "90%" if they put 9 aluminium cans into the recycling sack and one dirty dog food can into the waste bin.

However, when a traditional scientist defines participation he would probably relate the degree to something easy to measure. One short cut would be the relation of the weight of cans in recyclables to cans in waste. Probably he would also relate participation to the number of households which deliver recyclables to the recycling system. Perhaps he would take the quantity of recyclables in waste as the only reference to participation. Households delivering waste with less recyclables than a given defined limit would be defined as participants.

The easy way to measure participation is to ask people and believe their answers. In a pilot test, like in Bagaregården, it is possible to send a questionnaire to every single household and even to interview every single individual. In full scale tests this is not practical. All interviews and questionnaires have to be carried out as samples.

However, you cannot be sure that all individuals tell "the truth". Often they do not even know how often they put a glass jar into the recyclables sack or into the waste bin. Some of the respondents may answer as they believe you expect them to. Therefore it is of great interest to find a method of checking the validity of results from interviews and questionnaires. This check can be carried out in different ways:

a) Recycled quantity related to recyclables in waste.
b) Recyclables in waste from the test area related to recyclables in waste from other areas.
c) Reduction of waste volumes.

Avfallsgruppen has tried a lot of methods and finally used an interpretation of the results of three different methods: questionnaires, number of households which deliver recyclables at least once every five months and the amount of recyclables in waste. To this we have also added registration of the reduction of waste quantity through source grouping and finally the degree of recycling calculated as:

$$R\ (\%) = 100\ \frac{r_r}{r_r + r_w}$$

R = degree of recycling (%)
r_r = recycled recyclables (kg)
r_w = recyclables in waste

A special problem, interacting in all kinds of measurements of metals recycling, is the returnable can system introduced in Sweden in June 1981 in order to provide an aluminium recycling system. How can we measure the number or weight of returned aluminium cans from a perticular area? This problem is not yet solved.

5.2 Moving towards a source grouping system

5.2.1 In Bagaregården, 1978

While Avfallsgruppen was planning the Bagaregården tests in Gothenburg in 1978, 54 interviews were made in households that would be subjected to the source grouping system. The research group asked how people would react to being included in the experiment, and we met with almost only positive reactions. Several of the people interviewed asked why the experiment had not been made before.

The research group interviewed just over 70 persons in the 54 households and only twice met with the answer that the interviewees did not intend to participate in the new waste handling system.

This mentality materialized in quantifiable form as the amounts of materials collected. The group found that the population that was offered to have its recyclable paper, compostable materials (food and other organic residuals), glass and metals handled separately reduced its waste generation by 43%.

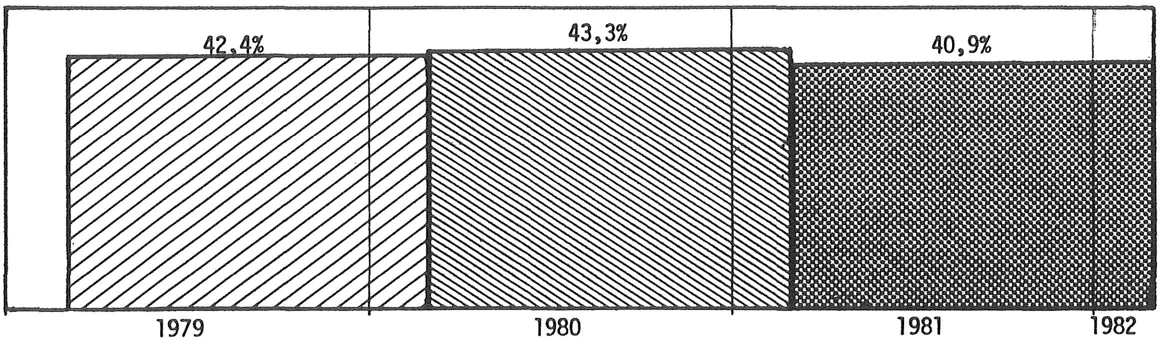

Figure 5.1 Reduction of waste quantity through source separation in Bagaregården.

A written questionnaire was issued to the entire population of the Bagaregården test area after the new waste handling system had been available for one year. This questionnaire was answered by 86% of the population. 70% of the population said that they delivered two or more fractions separated from the general waste, and over 80% answered that they delivered at least paper separately from their waste. As the tests were made in apartment houses it was impossible to find other methods of registering the real participation. Selection analyses indicate that the questionnaire answers are reliable.

When the group asked, after about one year´s experience, if it was more problematical to handle four fractions than one mixture, we received the unanimous answer that it was not, and that the change has been easy to get used to. One middle-aged woman explained her answers:

"In the beginning I had to think, every time I got residue, and it took me - of course - some time and made it a little bit complicated. After a while, however, I got used to it. Now I don't even think about it."

One woman described her family´s reaction as follows:

"The wife: It's no problem, you get used to it. The husband: It's complicated. The children (teenagers): It takes too much time."

This description might be a good general reflection of modern Swedish family life.

5.2.2 In the Nårab region 1980 and 1981

It is clear that people join the source grouping system on the basis of idealistic and ideological motivation. The answers to a succession of questions in the two questionnaires show unambiguously that the respondents expect neither financial nor other overt support. They avoid mixing just for their own satisfaction and their faith in a better materials handling system.

Two big sample tests made in the Nårab region indicate that with time people separate more and more of their residue. The quantity of recyclables glass and metals in the waste is significantly less in the second sample test, see Table 5.1. A part of the reduction can perhaps be explained as a consequence of the decreasing level of consumption but, referring to the collected quantity of recyclable materials, Avfallsgruppen cannot find any other explanation than more consistent consideration for the materials; a more consistent adaption to the source separation system.

Table 5.1 The quantity of recyclables in waste, the Nårab region 1981-1982.

Weekly amount of recyclables in waste	% of households May 1981	Feb. 1982
Paper		
<0.5 kg R/hh&w*	60 %	60 %
0.5-1.0 kg R/hh&w	16 %	17 %
Glass		
<0.2 kg R/hh&w	58 %	63 %
0.2-0.5 kg R/hh&w	16 %	14 %
Metal		
<0.2 kg R/hh&w	40 %	54 %

* kg recyclables (paper, glass and metals respectively) in waste per household and week.

In the Nårab region a questionnaire was made a few months after the tests began. This questionnaire included a sample test of about 600 households from a population of 6,000 housholds living in one-family houses. The questionnaire showed that 85% had accepted the source separation system.

The answers were checked by an address registration of sack delivery which showed that 54% of the population delivers at least paper every month, but 75% of the population delivers at least paper every second month. After 5 months more than 90% of the households had delivered paper to the recycling system, 50% had delivered glass and 40% had delivered metals.

5.2.3 The "traditional" nationwide paper collection system

I have not made - or found - any real registrations of people's reactions to the introduction of the nationwide paper collection system, introduced between 1972 and 1975.

A lot of paper collection tests were made in Sweden in the mid-1970's, including many superficial investigations. In a thin report from 1975 some of the results are exhibited as recommendations for interested municipalities /30/. Those recommendations include the observation that people separate paper for idealistic reasons, and do not expect financial support.

It can be seen that in Sweden 199,000 tons of newspapers and magazines were collected for recycling in 1982 - in 230-240 of our 283 municipalities. This means that about 42% of the quantity of newsprint consumed was recycled, just as an indication of the value of the paper as a recyclable material. Individual households received no financial support for these recycling activities.

The research group often meets people who complain about the scarcity or absence of paper collection, but we seldom meet people who complain about the existence of such a system. Most of those who complain about its existence have vested interests in waste incineration and waste-to-energy plants. They do not like separate paper collection because their organizations lose opportunities to make profits from the paper. The argumentation from their business point of view is irrelevant here.

5.3 Return to the mixture

When we introduced the source grouping system in Bagaregården we were told to expect a wave of dissatisfaction - perhaps protest lists and angry letters to the editor of the local newspapers. None of this happened either in Bagaregården or in the Nårab region. On the contrary - the source grouping was welcomed.

When we discontinued the pilot project in Bagaregården we were told to expect the conventional handling to be welcomed back. This did not happen when the Bagaregården tests were discontinued, after three and one half years in practice.

A few weeks after the change back to the conventional waste handling system both the sanitation department and the research group received a letter with protest lists enclosed. These lists were signed by 72% of the 90 families in the test area asked.

In addition to the protest against the discontinuation there was a demand for a continuation of the tests and an expansion to neighboring parts of the city.

This reaction may be difficult to accept, but is simple to explain. When the test ended, the people of the Bagaregården test area had to act against their convictions. From their point of view they had to return to something bad.

This may be the most important result of the Bagaregården test; in this "critical" situation people have given spontaneous reactions in favor of the source grouping system.

5.4 Conclusion: Guidelines for giving people motivation

In chapter 2 it was stated that people participate in source grouping systems on an ideological and idealistic basis. They seldom or never ask for financial support. This and the experience described above helps us to create the four following guidelines on giving people information - instructions and arguments - about waste and recyclables handling.

1. Explore the population's view of waste handling, scarity of raw materials and environmental protection.

2. Distribute information in these fields, i.e. letters or leaflets, which build upon people´s previous knowledge.

3. Contact the individuals via various media: newspapers, TV, radio, posters, etc.

4. Give the individuals frequent reinforcement of the results of their separation activities.

These points give basic verbal and written information. There must also be a convenient, well-managed collection and distribution system - "I must be able to see that my consideration for the materials is followed up by equal consideration from the authorities" - and not least important: the collector must be able to make sure that the separated materials will be used for the purpose that is stated to the individuals. If you collect paper for recycling it has to be recycled - not incinerated - even if you are paid better for selling the paper to a incineration plant.

This means that it is very important that the people and/or organizations that give the information believe in the message, and formulate it on the basis of the raised consciousness that can be found in a "normal" population. This also means that the collection system must be designed on the basis of what the collector knows that the population wants to separate, even when one or more materials cannot be sold at prices high enough to balance the collection costs.

6. THE TECHNICAL AND ECONOMICAL BASIS FOR CREATING A SOURCE GROUPING SYSTEM

6.1 Deciding what materials to keep separate

6.1.1 Motivation for separate collection

Many factors govern the choice of materials to be kept separate from the mixed waste stream. There are two main justifications for source grouping:

recycling which is: like picking the raisins out of the cake, without caring about the fate of the rest of the cake,

and pollution control (influencing the stream of hazardous components) which is: more like cutting off the burnt edges of the cake, to increase the possibility of having the remains of the cake consumed. The waste becomes easier to handle and its environmental costs decrease.

The following factors can be added to these main factors: the quantity of every special material, prices on the market, kind of pollution risk, etc. Based on these factors, the household waste can be classified as in Table 6.1.

Not all the headings in the table are self-explanatory. A market can exist because there is material for sale or an established need for the material(s). A potential market may lie in the knowledge of how a special material can be recycled in a situation when there is no demand for that particular material. Another question is how far you can fulfill purchasers´demands for quality or purity.

Table 6.1 Household Waste: characteristics which promote source grouping.

	Market existing	Market potential	Amount	Easy to handle	Easy to identify	Hazardous
Paper	++		+++	+++	+++	
Compostables	(+)	++	+++		+++	++
Glass	++			+	+++	
Metals: Fe		++		++	+++	
Al	+++			++	+++	
Textiles	+	++		+++	+++	
Plastics	(+)	++		++	+	(+)
Solvents					++	+++
Miscellaneous combustibles		(+)	++	+		(+)
Pharmaceuticals				++	++	+++
Batteries				+++	+++	+++
Miscellaneous non-combustibles				+	+	

+++ excellent ++ fair + poor

The degree of hazardousness can be discussed. In the past the danger of infection was the absolutely most important pollution risk, while today the ordinary sanitary situation makes that danger proportionately small. Today´s problems are basically related to poisons, especially persistent and eco-accumulating ones. This discussion is complicated, as it must also include concentrations, total amounts and local circumstances.

A special part of the environmental issue is the working environment of the garbage collector. For example glass is hazardous for him when he handles a refuse sack containing thrown away glass, and so glass separation in the households would improve his working situation.

6.1.2 The basis for the choice

The choice of materials for source separation will always be related to the collection technique being used. The degree of ease in handling each individual material is central to the collection technique. In the Bagaregården tests, paper, glass and metals were chosen because they are easy to recognize and handle, there was a market for each - although the markets for glass and metal cans were weak - and there were local incineration process based motivations for keeping them out of the plants. Compostables were chosen because of the quantity, the (possible) market, the potential danger of incineration (HCl-release from NaCl) and the experimental value of studying people´s reactions to handling these messy materials separately from others.

The Bagaregården tests were a small experiment but they produced a lot of basic data. The scientific value of the tests was much higher than the practical experience of a special collection technique. I consider the Bagaregården tests as a fundamental kind of research on source grouping, while the Nårab Region Recycling System is a full scale test where a collection system is applied - on the basis of the Bagaregården findings.

The purpose of an application is to confront reality. The choice of materials has to be related to the choice of collection system and the risk in terms of faith and finances. Miscarriage of mechanical separation costs money for 15-20 years. Miscarriage of source grouping cost money for 5-7 years, but it costs faith for a very long time - exactly how long we do not know.

In the present situation, the Nårab system was constructed with consideration for security, recycling and operability. Paper, glass and metals were chosen initially, and textiles were added later. All these materials are dry and were easy to collect in the specially designed four-chamber vehicle. They can all be stored for a long time in the homes without any sanitary problems. They can also be handled using the same container or sack system.

Compostables, however, place different demands on the collection system. They must be collected often - once a week or once a fortnight. They need a hygienic container/sack system that works both in terms of the collection activity and the composting process. It would have taken too much time to specially develop such a system for the Nårab region.

6.2 Source grouping techniques

6.2.1 Considerations

Traditionally recyclables and waste are collected on separate trips, and different techniques are often applied to the waste and the recycling systems, i.e., recycling requires an extra collection route, added to the waste collection.

In Sweden waste is almost always collected packed in sacks (70%). Some municipalities use returnable metal or plastic bins. Paper is usually collected from sizable containers - 1.5-12 m^3 - or "systemlessly", i.e., the households provide the collection system with packaging for the paper. Returnable bins are very seldom used.

This situation is natural when dealing only with waste and recyclable paper, where the paper is collected by a special contractor. When the source grouping system expands, the organization also has to be developed. A simple/unreflected transfer of today's waste collection system to the new materials handling system would result in a separate trip for every new material, a situation that would quickly become unwieldly.

The most important difference between waste collection and recycling may be that waste has to be collected close to the source. Recyclable materials, on the other hand, can be collected either close to the source or at recycling centers, each of which can serve thousands of households.

In this paper I concentrate on the source-directed systems. According to the investigations made by the Avfallsgruppen, there is no demand for centralized systems, although they are not unusual elsewhere in Europe. Nearly all glass collection on the European continent as well as in the British Isles is made using such centralized systems.

The possibility of integrated collection must be investigated, including construction of new vehicles. There are some on the market, but they are generally constructed as part of a total system including collection and processing as well as recycling.

To examine the possibilities for constructing such a vehicle, it is also necessary to know what kind of container/sack system will be used. The container/sack system and the vehicle are mutually dependent. There are two types of integrated collection systems, separate systems for waste and for recyclables, and systems where waste and one or more recyclable materials are collected together in split vehicles.

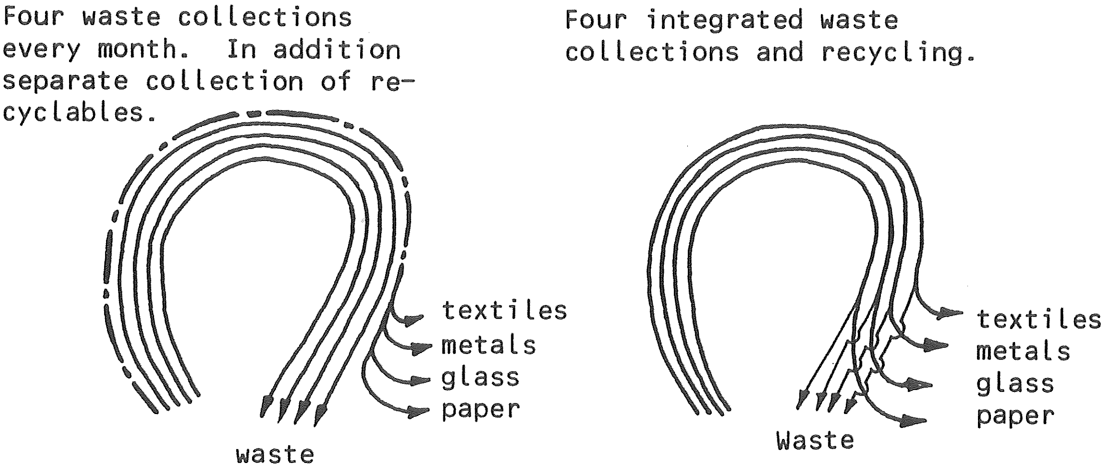

Figure 6.1 Two types of integrated collection systems.

The first system is easy to organize. It is very much like the normal situation with separate paper collection parallel to the waste collection. The problem is just to find corresponding container/sack systems and vehicles for collection and transportation.

The second system is more complicated because it requires more involvement from the individuals. It is very difficult to keep the collection schedule in mind: which week will which material be collected? This system seems to need more "light" technology than the first system does, new multi-sack holders, etc. which make the collector independent of the individual's help in carrying the right sack to the edge of his property on the collection day.

Normally financial issues and investment costs are the most important questions for the municipalitiy or its contractor. Therefore it is desirable that the new technique as far as possible be borrowed from other materials handling systems. Development of new techniques is often too expensive for a single municipality.

6.2.2 Container/sack systems

The nationwide paper collection system generally operates without any official container/sack system. It is systemless, which means that the individuals pack their paper in paper grocery bags (too often in plastic bags!). The individuals pay SEK 0.60:- (Jan. 1984) for each bag at the grocery store, which makes about SEK 20:- per year, for some households SEK 50:- per year. This cost is concealed, and almost nobody wants to see it. Many people probably consider this a way of recycling of their grocery bags.

Various kinds of bins and containers are used. In addition to the very big ones, there are several that hold 0.6-1.5 m^3. The best purity of paper is obtained in the containers equipped with "mail box inlets".

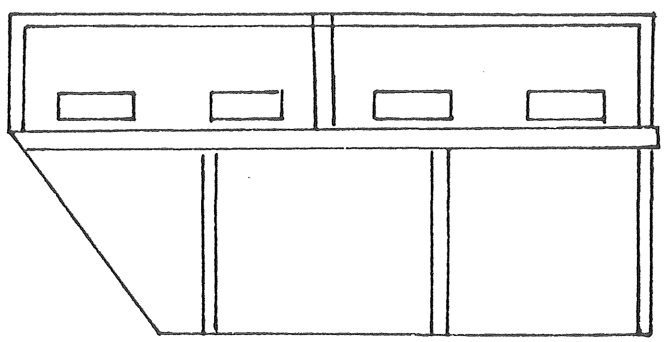

Figure 6.2 Container equipped with "mail box inlets".

In the Nårab region 0.6 m^3 plastic containers are used in areas with apartment houses. Each container serves 50-100 households. In same parts of Gothenburg 0.3 m^3 plastic and aluminum bins, each serving 15-20 households, are used. In Örebro 1 m^3 containers with letter box inlets are used, each serving 200-300 households in apartment houses. These containers cost about SEK 6-10:- per household per year.

Some collection contractors use disposable paper sacks for the paper collection system. This is the case, for example, in the municipality of Höganäs. This type of sack costs the contractor SEK 20-30:- per household and year. This is about the same cost as households bear in the first example.

A split garbage and recycling bin was tested in Konstanz, West Germany /16/. This specially designed bin is an integrated part of a total system - the Dornier System - including refuse bins, vehicles and a separation plant. See Figure 6.2, page 42. The individuals were instructed to put their waste into the larger chamber and a mixture of returnable paper and glass into the smaller chamber. The bin was emptied into a split compaction vehicle. This bin looks very much like a conventional garbage bin, which is advantageous in areas where garbage bins are used. It is also easy for the garbage man to handle, and so the recycling generates no excess work. The system´s drawback is that the individuals have to mix two recyclable materials, making their consideration for the materials low.

In Bagaregården the tests showed that conventional bins and containers can be used for separate collection systems. This experience also shows, however, that those containers and bins are not always very practical. The 150 liter cylindrical iron bin used for the glass and metals mixture was too heavy. A plastic bin of equivalent size would probably suffice.

The Nårab system uses a type of woven polypropylene (PP) sack for separate collection of dry recyclables, that has long been used by the post office department (as a mailbag). The sacks are personal, to encourage individual responsibility for their care, and must be brought back to the correct adress after emptying. Thus the collection sequence takes a little more time than it would if the recycling man could shift the sacks to different addresses. The sacks are cheap, and the four sacks costs only SEK 5:- per household and year.

6.2.3 The collection vehicle

The Dornier collection vehicle used in West Germany is a compaction vehicle split into two backward facing chambers, separated by a thin wall. This wall corresponds to the wall in the bin. Two whole bins can be emptied at the same time. As both chambers are compacted, the glass is crushed, and further mixed with the paper. This mixture is later separated using a special process, illustrated in figure 6.3.

In the Bagaregården tests no special vehicles were used. Collection took place using normal compaction vehicles (for paper) and open flat-topped trucks (for compostables and the mixture of glass and metals). The compostables were contained in plastic sacks to avoid sanitary problems during the transportation. The glass and metals mixture was transported in the bins to avoid the problems of emptying the bins on the truck platform. Although this was a simple temporary solution to the transportation problem, it was also a very expensive one.

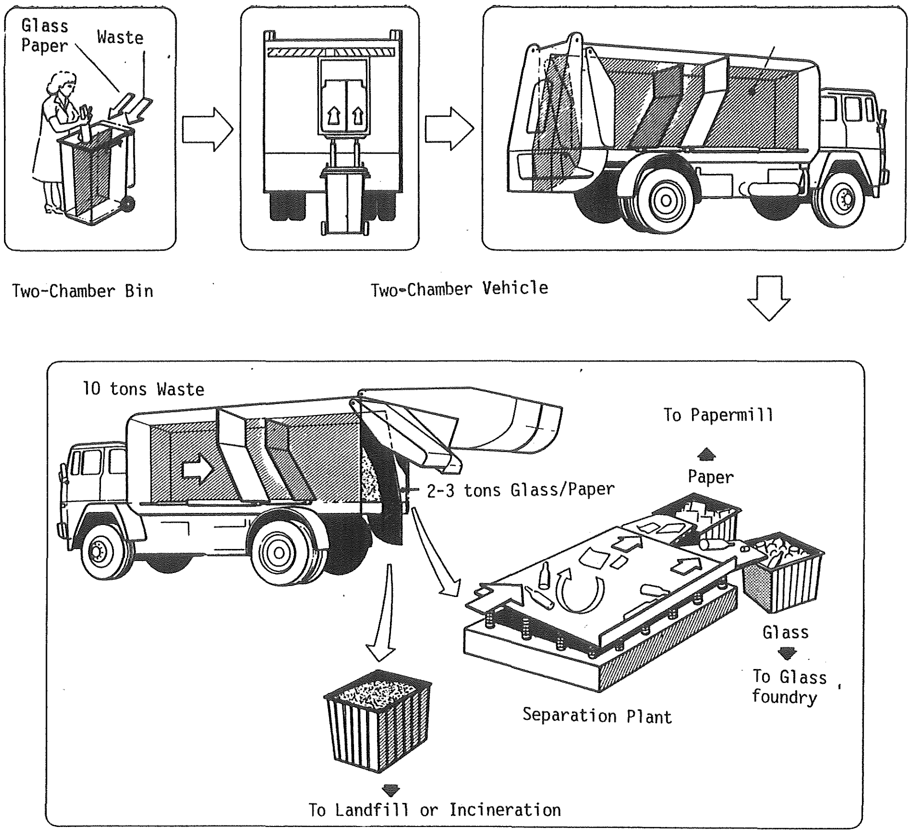

Figure 6.3 The Dornier System. Residue bin, vehicle and separation process.

For the Nårab recycling system, a specially designed collection vehicle was purchased. The vehicle was constructed on the basis of the experience of a pilot test made in the Elfdalen area in the municipality of Klippan. The pilot test ran for one year, during which a modified flat-topped truck was used.

Figure 6.4 Truck previously used for latrine transportation, modified for used in the pilot tests in Elfdalen, Klippan.

At first this test vehicle was split into three different chambers, one each for paper and glass and one for a mixture of metal cans and textiles. However, this mixed materials system was found to be impractical from a collection point of view, and the vehicle was modified to carry four separate materials.

The new vehicle was constructed on the basis of the experience from the pilot test, extensive discussions and many concrete proposals from a special "innovation group". It was developed out of existing technology, and is a new application of the "Swinger" idea; one conventional backward facing piece of equipment behind one sideways turned three chamber piece of equipment. The backward facing one - the paper chamber - is 7.8 m^3, while the sideways turned ones - the glass, metals and textile chambers - are 1.8, 1.6 and 2.8 m^3, respectively. The vehicle has to make two trips with paper before the other three chambers are filled up. In the collecting scheme in which the vehicle operates, this means that the paper chamber is emptied two or three times per day.

Figure 6.5 The Squirrel. A four-chamber vehicle constructed for the Nårab Recycling System.

This new vehicle, "The Squirrel", is useful for collection in the villages, but in the countryside the system does not operate well. The problem there is that the recyclable materials are collected only four times per year, and it is sometimes difficult for people to remember the collection days. If the sacks were kept outside, near the waste sack, the collection system would be independent of the individuals' abilities to remember those four days. If that were the case, it would be simpler to use a split vehicle, which collected waste and one of the separated materials every second week. If such a vehicle were used in the villages, however, a completely new organization would be required.

The Dornier vehicle cannot be used in the Nårab system, because it requires the special residue bins. The split vehicle that can be used in the Nårab region must accept the returnable sacks, and the chambers' volume proportions must be very like the proportions of compressed waste and paper. No such vehicle is available today.

Some other vehicles are presented in the literature. In the German handbook "Müll und Abfall Beseitigung" four vehicle propositions are presented /29/ but only two of them have been realized, to my knowledge. In a Norwegian review of systems for separate collection /15/ two American proposals for vehicles are also presented. One of these is a backward-facing three-chamber vehicle, very much like "The Squirrel", another carries a compaction chamber behind two sideways containers for recyclables.

During 1984, "Squirrel-II" was developed, and it is being tested beginning in the autumn of 1984. The new vehicle is based on the experience gained in using "Squirrel I". The swinger is replaced by bands which feed the different chambers. Thanks to the new feeding system the chambers can be built with roofs, which minimizes the risk of losing collected materials owing to wind. The noise from the vehicle is also decreased. When emptying the chambers, the bands are reversed.

6.2.4 Separation plants and storage

The collected recyclables are not 100% pure. They often have to be cleaned before they are used in a production process. The need for cleaning operations depends on the process. Glass used for production of new packaging glass has to be extremely clean, while in production of plastic pallet blocks as much as 10% impurities in recycled plastics are accepted.

Paper is generally quite pure in relation to acceptance demands made by the production process. The paper collected from households is simply manually cleaned of plastic bags and other "major" impurities. Depending on the qualities of paper and the quantities of impurities found in the collected paper mixture, the paper is used for different purposes. The paper collected in the Bagaregården test was so clean that it needed no cleaning before delivery to the paper mill. The purity was checked in two analyses and it was found that the impurities constituted less than 1% by weight. However, Avfallsgruppen once found crushed window glass mixed with the paper, and in one waste storage chamber there were ordinarily one or two bags of waste in the paper bins. The paper collected in the Nårab region today is so pure that it can be delivered directly to the paper mill without any further inspection or cleaning.

Glass collected mixed with metals in the Bagaregården tests carried 1-5% impurities. The percentage of impurities was measured on every collection occasion, and the results are presented in Figure 6.6.

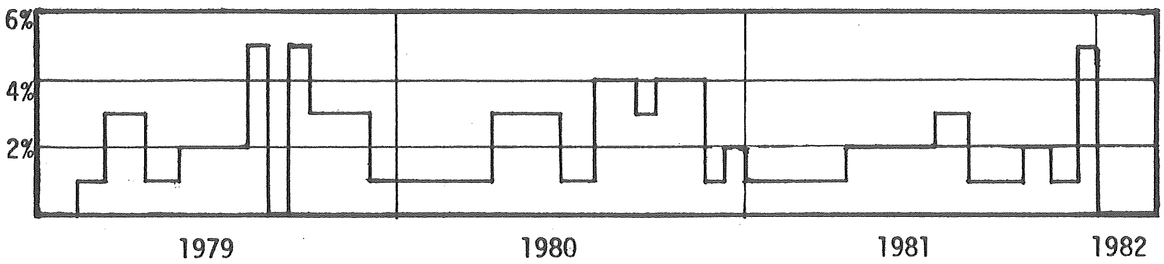

Figure 6.6 Impurities in glass and metal fraction collected in Bagaregården.

Glass collected in the Nårab region is nearly 100% pure. The recycling man inspects the glass after emptying the sacks, before the glass is swung into the vehicle. If he finds any foreign material or product, he picks it out and lets the deliverer (the sack owner) know that he wants pure glass. (see information leaflet, Appendix 1). This system is a good guarantee of the quality of the glass. There is, however, a problem when bigger quantities of glass from glass bins or small containers are emptied into a vehicle. It is not easy to remove a single crushed cup or dish in a quantity of more than 100 liters of glass. In the Nårab region the only impurities ever reported are isolated cases of pottery.

The differences in the impurity level of the glass in Bagaregården and in the Nårab region can be explained by the differences in the collection systems. In Bagaregården a mixture of glass and metals was collected, and a mixture always runs the risk of containing impurities, while in the Nårab region the glass is collected separately. In Bagaregården the individuals had to carry their glass and metals to the waste chamber, and most often they carried the glass in some kind of bag. This bag often went into the bin along with the glass and metals mixture. In the Nårab-region, however, the individuals generally bring small quantities of glass to their individual sacks more often, and do not need a bag to carry these bottles and jars.

As every glass collection system carries impurities, which can be hazardous or troublesome to the production process, the glass must be cleaned in a central separation plant. The Swedish glass foundries use a separation system including crushing, sieving, and magnetic separation, but no manual inspection or separation, see Figure 6.7. In West Germany, however, manual inspection is the most important part of the separation process (Figure

6.8). The human eye can easily distinguish pottery from glass, simple machines cannot. Pottery and stoneware are the only problem related to impurities in separated glass in Sweden today.

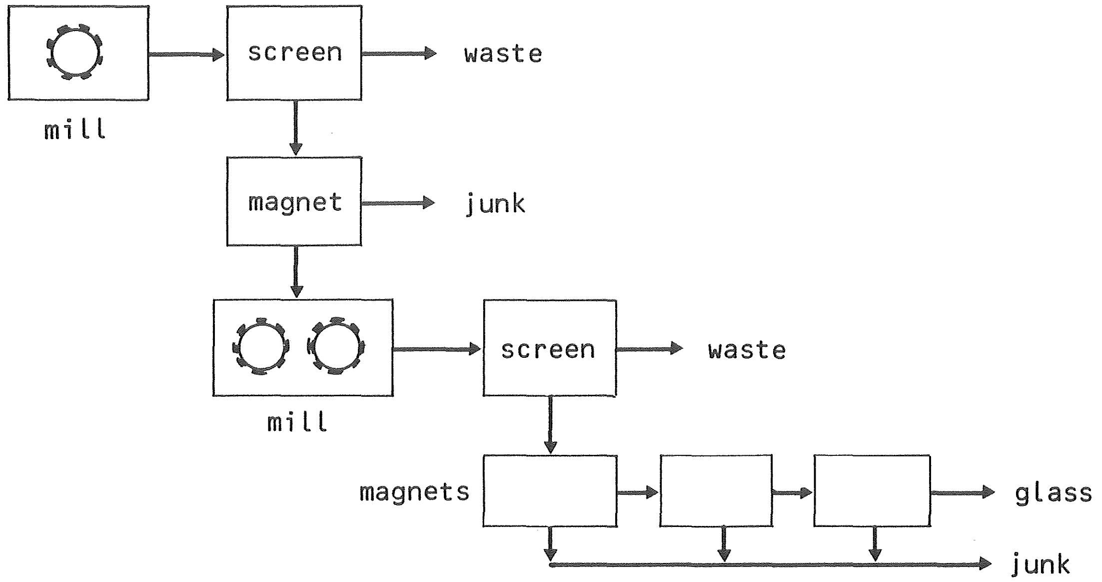

Figure 6.7 Glass separation plant at the Hammar Glass foundry.

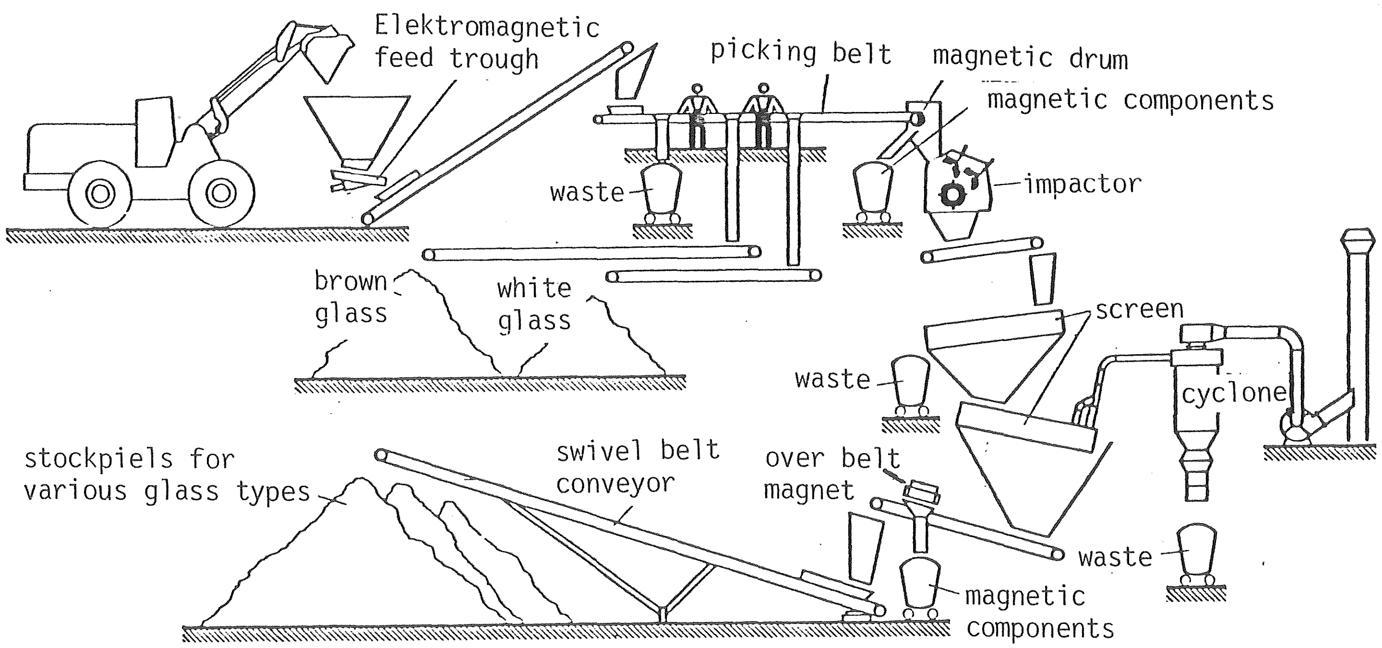

Figure 6.8 Hazemag's glass cleaning plant.

Metals have to be separated into magnetic (ferrous) and nonmagnetic metals. Such a process is easy to design, but after magnetic separation the cleaning process is not yet complete. The magnetic fraction is often impure with food waste, which - even in proportionately small quantities - can make the recovery process problematical. Can design also contributes to the problems. An iron can is not pure steel, it is a mixture of metals, including tin and lead. Tin does not alloy to the steel, and lead destroys the basic casing of the melting ovens. Tin and lead cannot be separated from the steel using simple or light techniques, and therefore the melting process and the use of the recycled metals have to be adapted to the quality of the recovered metal. This means that metals recovered from household residuals cannot be used for high quality steel production. However, the recovered steel is good enough to make armouring-iron, a product that is in relatively large demand. This also means that this kind of recovered metal ought to be remelted in ovens with acid casing or, if this is not possible, melted just before the (basic) casing is to be renewed.

Textiles were collected for the first time in the Nårab region in August 1981, with excellent quality. A lot of the textiles had been cleaned and were ready for use. After some time, however, the textiles began to contain more rags, but were still of high quality. The best measurement of the quality is the disposal: some of the textiles are sold to a second hand shop.

However, the textiles do contain some impurities. Shoes, boots, waterproofs, etc. are found in the textile fraction. All kinds of textile separation has to be done manually, and so this type of impurity is unimportant. Today, when some of the textiles are sold to a second hand shop, these "impurities" may even be of some value.

The collected materials have to be stored until large enough quantities are collected that their value justifies transportation to the buyer. In the Nårab region, paper is stored in 30 m^3 containers at the Hyllstofta landfill site and at the Örkelljunga transfer station. Glass and metals are stored outside on hard ground. This storage is the simplest possible kind. The only demand is placed on the ground, which has to be hard and not contribute stones, pieces of concrete, etc. to the materials. The steel fraction of the metals should not be exposed to too much moisture, but it seems to be sufficient to cover metals being stored with a tarpaulin. The textiles, however, have to be stored dry. Skånemiljö stores the Nårab textiles packed in corrugated paper boxes in a truck garage. These packages are also transportation packs. At first the textiles were stored outside in a covered container, but this method was expensive and risky for the material. The textiles could get wet, which decreased their quality and value.

6.3 Organization

Source grouping is not a kind of waste treatment, and cannot be organized as such. Rather, the collection of source grouped materials is a link in a production system and must be organized accordingly. This means that those municipalities and contractors who want to deal with source grouping have to change their organizations and build up new structures based on new conditions.

The waste problem and nature conservancy are questions of a universal political nature. Consequently, municipalities - in their roles as political structures - are the most natural principals for the recovery organization. Contractors, however, are a part of private commercial and industrial life, and have - in their role as actors in that part of the economy - a better chance of finding markets and acceptable prices for the materials collected than the municipalities.

Acting in the market means acting a part and playing a special role, which is foreign to the municipalities. The municipalities are public, open, official organizations, while actors on the market have to be sealed off to safeguard their business transactions. Those two roles are impossible to play simultaneously under normal conditions. In addition, the municipalities are not used to competing for marketing-oriented staff. This is a problem, especially for the small and middle-size municipalities.

It is conceivable that the most effective organization is a mixed one, with the municipality at the head and one or more contractors as executors. This situation makes both the public role and the commercial one possible. The question of the number of contractors must be referred back to the collection situation. One or more contractors can be used for materials collection. If more are used, to collect one material each, the collection will probably be quite expensive.

Contractors may, however, be specialists on their materials, and thus be able to place them well. This fact is of special value during the introduction of the source grouping system. Under dynamic market conditions, this organization facilitates growth of the number of potential buyers.

Using just one contractor for the collection is probably cheaper, and makes it easier to develop a trusting relationship between the municipality and the contractor, as well as to supervise the contractor.

In the Nårab region the organization is very mixed. The municipalities have a corporately-run sanitation company. This company has a contractor for waste collection and transportation. The waste handling company´s, interest in recycling has grown with support from the local politicians. Since the waste company and its contractor worked well together - and had interests in common in recycling - it was a short step to add the recycling to their joint business. The contractor also had good contacts on the commercial side. Today Nårab undertakes the information to the households, and Skånemiljö, the contractor, deals with the collection and disposal of the materials. It seems to be a harmonious situation, but it is difficult to evaluate after such a short time.

In Gothenburg (Sweden´s second largest city, population about 500,000), the sanitation department (GSR) is studying the possibility of building up a municipal company to handle the recyclables. Today GSR collects only a part of the paper that is collected in the municipality. The majority of paper is collected by various contractors, but all glass for recycling is collected by GSR. The new municipal company would collect, clean and sell all kinds of recyclables that can be collected in the municipality. GSR's potential ability to create that company and succeed comercially is regarded as good. GSR already has commercial experience through its production company, which produces waste management equipment and disposes of it on both nationwide and international markets with relatively good success.

6.4 The Economics of Recycling

6.4.1 Source grouping costs and benefits

When discussing calculation of source grouping costs and benefits, it has to be understood that all kinds of costs and benefits are "alternative" costs and benefits. Source grouping is an independent activity , and must be initially calculated accordingly. Later, the cost-benefit result has to be compared with the cost-benefit analyses for other alternative ways of handling residuals. This means that all extra costs for vehicles, container and sack systems, storage, staff, organization, disposal on the market, etc. will be entered as specific to the system. All kinds of benefits, income from selling material, positive reactions from people, changed consumption habits, etc., will also be made specific to the system. This is elementary.

In addition, there are all the non-monetary benefits the source grouping system gives to the conventional waste collection system. Such benefits can be exemplified as lighter sacks (easier to carry), less risk of staff injury from crushed glass, less waste to transport, etc. There will also be both added expenses and benefits to the landfill or in the waste disposal plant. Costs may include loss of energy in waste-to-energy plants, loss of cellulose in the compost, loss of magnetic metals for separation, and loss of waste food for methane production in the landfill. Corresponding benefits may include less cost for maintenance of plants (less wear and tear from glass and metals), less pollution (less metals, acids and organic pollutants in flue gas and less pollutants in compost and leachate), smaller quantities of process residuals (ashes from waste-to-energy plants, and refuse derived fuel (RDF) from composting plants, which seldom can be sold today).

There are also other benefits, difficult to specify, but realistic to include in the calculation. Such benefits include: saved volume in the landfill, which gives practically no benefits until the day the landfill would have been filled if it were run without the supporting recycling system, and the possibility of incinerating waste from other municipalities in a situation where the recycling system has freed oven volume or incineration capacity. If there is no opportunity to help other municipalities with their waste, there are no benefits of this nature, but neither are there extra expenses for the waste handling system. Instead, some money is saved in wear on plants.

6.4.2 Market prices (Jan 1984)

Today, much recovered material is of proportionately low value on the open market. In the early 1950s the paper collected for recycling was valued at approximately SEK 1,100 per ton (in 1984 values). Today the value of recycled paper is estimated at SEK 350-400 per ton (as a recycling material) while the net value of the incineration energy given is estimated at SEK 500 per ton.

Today the value of glass is estimated to be SEK 100 per ton for colored or mixed glass free from china and stoneware. White glass is worth up to SEK 130 per ton f.o.b. These prices correspond well with the prices on the continental European market. However, since the Swedish devaluation in 1982, it has been difficult to compare Swedish prices with prices in other countries. Today, for example the exchange rate of USD 1 is SEK 8.50, but in the 1960s, with stable foreign exchange markets, USD 1 was worth SEK 5-5.50, which was more consumption-eqvivalent than today´s exchange rate.

Magnetic metals are difficult to sell, and are normally sold at low prices, SEK 30 to 50 per ton. Prepared cans, however, are worth more. Flattend cans of a density higher than 800 kg/m^3 have been sold for up to SEK 300 per ton. However, the steel mills are generally unwilling to buy this type of scrap metal. The market is extraordinarily unstable.

The aluminum market is expanding, and aluminum is easy to sell. The prices are over SEK 2,000 per ton, depending on the buyer. Aluminum also has to be compact to obtain the best prices.

The food waste market is "grey", and prices are difficult to define. Food waste is often carried away without open monetary transactions. It is only a matter of speculation as to what concealed transactions do take place. I have noted some cases where the wasted food is sold to farmers for the symbolic sum of SEK 5 - 20 per ton.

There is no market for unprocessed compostable materials today. Compost of certain qualities, however, can be sold under special circumstances. Compost produced in mechanical separation/composting plants is seldom sold on the open market. Some municipal organizations, however, have bought some compost from the municipal composting plants for SEK 20 - 60 per ton (1982). On the open market conventional topsoil costs around SEK 80 per ton. The compost produced in the Bagaregården test was not sold, it disappeared to allotment gardeners. There was more supply than demand, but for practical reasons there was no chance to sell the compost and determine the market price.

It is, however, more possible to find a market for compost made of source separated materials, than for the mechanically separated compost. The source separated compost is not entirely pure, but there are so few impurities - compared to mechanically separated compost - that they are probably negligible provided that the processed compost is mechanically sieved.

6.4.3 The Nårab reality

The Nårab recycling system required three major investments: the vehicle, the collection sacks and the storage arrangements at Hyllstofta landfill site. Skånemiljö will have written off the cost of the vehicle after seven years, while Nårab has written off the costs of sacks after the first year, and the invests at Hyllstofta landfill site will be written off after ten years.

The total monetary costs for the recycling system have been extracted from the Nårab accounts and 1983 are shown in table 6.3. The table needs to be supplemented with the following brief annotations:

- o Half the collection vehicle costs are costs for personnel.
- o The sacks are written off after the first year, but probably have a "technical lifetime" of more than three years.
- o During the first years there are extra costs for the sacks, while the sack construction is developed on the basis of field experiments.
- o "Miscellaneous" includes costs for information, marketing, etc.

Table 6.3 Distribution of costs. Nårab Recycling System 1983 (SEK)

	Apartments houses	One-family houses	Rural areas	Total
Container/sacks	50,170	26,300	13,206	89,676
Collection vehicle	54,500	209,900	108,000	372,400
Depots, stock & transportation	43,536	95,700	17,564	156,800
Miscellaneous	5,139	14,600	7,302	27,041
Total	153,345	346,072	146,072	645,917

Apart from the paper market, the market for recycled materials is unstable. During 1983, paper prices rose from SEK 360/ton to SEK 385/ton for cleaned and baled paper. Textiles were sold at different prices depending on quality. Unsorted textiles could be sold for SEK 200/ton, while usable clothes and cotton rags could be sold for SEK 1,000/ton.

Glass prices are rising and delivery conditions improving. In 1982 Nårab delivered 60 tons of glass to Hammar's Glass Foundry.The glass was rejected as unpurchasable, owing to small quantities of chinaware in the glass. Later, however, the Nårab glass was accepted, and was bought for approximately SEK 100/ton glass (delivered on truck at Hyllstofta Landfill Site). Today they are paid SEK 130/ton glass (on truck) for first quality and SEK 65/ton for second quality. All prices are for colored glass. White glass can be sold for an additional SEK 30 per ton.

There is no real market for metal cans, except for the aluminum ones. Aluminum can be sold for SEK 2,000/ton or more. Ferrous cans - after preparation - can be sold for SEK 200/ton (on truck) to the iron works, but that price is preliminary, and the iron works do not accept long term contracts.

The mixed metal fraction collected in the Nårab region is sent to the Landskrona Waste Disposal Plant where aluminum and ferrous cans are separated magnetically. The separated cans are later compressed and cleaned from laquering and organic waste in a ball mill. The separated and prepared metal fractions are stored in containers and later transported to aluminum and iron works.

Looking at the real income in Nårab for 1983 we notice that only paper and a small quantity of textiles were sold that year. Glass and cans were delivered in early 1984. Studying the income from 1983, we therefore have to calculate on the basis of income based on the market prices for 1983 and the condition that the whole collected quantity of all materials could have been sold. These results are presented in table 6.4.

Table 6.4 Calculated income (market value). Nårab Recycling System 1983.

Material	Amount tons/year	Price SEK/ton	Squirrel SEK/year	Income Apartm.h. SEK/year	Total SEK/year
Paper	1048	385	262,600	139,800	402,400
Glass	125	100	12,500	-	12,500
Metals	29	-	-	-	11,300
Al	3.2	2,000	6,400	-	-
Fe	25.8	190	4,900	-	-
Textiles	31	500	15,500	-	15,500
Total	1232	-	301,900	139,800	441,700

The accounts for 1983 thus show a loss of SEK 204,200 or SEK 165.6/ton collected materials. This cost may be distributed into SEK 190,700 for "Squirrel" collection (SEK 219/ton) and SEK 13,500 (SEK 37/ton)for paper collection from the apartment houses.

However, the recycling system saves on volumes at Hyllstofta Landfill Site. In 1983 the landfill was estimated to a total cost of SEK 53.7/ton of disposed waste. That number can be used as the monetary value of saving landfill volumes, in which case it gives the recycling system an income of SEK 53.7/ton recycled materials or SEK 60,000/year. That means a loss in 1983 of SEK 144,000 or SEK 117/ton collected materials.

If the losses incurred thorugh "Squirrel" collection are distributed back to the costs of household waste disposal, SEK 190,700 would have to be added to the landfill costs as an alternative cost. The alternative cost of "Squirrel" collection plus landfilling is a mechanical separation cost, and therefore has to be distributed over the waste collected from one-family houses and from the countryside, which gives a total waste disposal cost for those areas of SEK 93/ton, a great increase in disposal costs. However, a comparison with other southern Swedish municipalities sheds a different light on those expenses.

Table 6.5 Comparison of waste disposal costs in four different municipalities in southern Sweden.

	Treatment method	Including transportation		Costs SEK/year
Halmstad	Incineration	yes		185
Båstad	Landfill	no		90
		yes		185
Landskrona	Separation +		gross	437
	composting		net	370
Malmö Region(SYSAV)*	Incineration	no		<0**
		yes		100

* The municipalities in the Malmö-region have a joint company, SYSAV, operating the waste-to-energy plant in Malmö and a wide transportation organization serving the plant with waste.
** The incineration plant provides some income although the exact price is difficult to calculate. Here the income is used to balance a part of the transportation costs, as is done by SYSAV in their calculations.

The table shows something very important - the Nårab System of residuals disposal is not more expensive than any other waste disposal method, including incineration in a waste-to-energy-plant. The SYSAV waste-to-energy-plant operates at a profit - calculated in terms of the energy production system - but since the plant requires a very large collection area and therefore also a wide transportation organization, the transportation costs must be included in the disposal income. This makes disposal costs about SEK 100/ton.

It must be noted that the comparison is made using the waste disposal tariffs in the different municipalities, except in Landskrona, where the costs and benefits are given as real costs and benefits. There may also be some small differences in the calculation background in the different municipalities.

It may be of interest to note that rural collection is expensive. In 1983 it accounted for 80% of the losses in the Nårab recycling system. Therefore, there is great financial motivation for changing the collection techniques and organization in the countryside.

In the municipal economy, there is one sector that can never be translated into monetary terms. A recycling system relates to several of those non-monetary costs and benefits, such as:

- o environmental costs (more vehicle exhaust),
- o environmental benefits (less landfill leakage),
- o "confidence capital" fund management,
- o political willingness and power to realize the voters' wishes, etc.

Through the Nårab investigations we have found that people want more recycling of residuals. In addition, they want to take personal responsibility for that recycling. This is probably the most important factor - besides the environmental costs and benefits - in the non-monetary calculations.

To the extent to which this is true, it becomes possible to translate the value of those effects into monetary terms, and I find that a cost of SEK

165/ton recycled materials is accepted, and is balanced by non-monetary benefits. This is, however, true under the special political conditions existing today in the Nårab municipalities of Klippan, Perstorp and Örkelljunga.

The calculated result - a loss of SEK 144,000 - will be borne by the individuals, through the waste disposal tariffs. This means that the households have to pay SEK 16.6 per household and year (or SEK 0.31 per household and week) for the satisfaction of recycling their residuals.

It is against this background that source grouping should be discussed. Are the individuals ready to spend less than half a Swedish krona per week on the recycling system, or could the monetary cost-benefit balance be a useful carrot to hang before the horse?

I cannot find that the monetary costs and benefits can be reasonably discussed as long as they would not be more than 5-10% of the sanitation tariff for one-family houses and about 10% of the cost of the plastic bags used for the garbage. The benefits are found on another level - the satisfaction of contributing to environmental improvements.

The costs and benefits that derive to the national economy from different recycling systems are very difficult to calculate, because there are a lot of external effects such as foreign trade charges, number of employees in different sectors, energy saved in industry, etc.

To make such a cost-benefit analysis operative in monetary terms I have chosen to calculate the value of the energy saved by using recycled materials instead of virgin raw materials. As energy prices are not constant, I have chosen to present the results as both oil prices and coal prices (Jan 1984).

Calculating in terms of one-turn recycling, the energy and money saved by recovery can be summarized as in Table 6.6.

Table 6.6 Value of recycling to the national economy.

Materials	energy saved*	value recovered	
		oil	coal
	GJ/ton	SEK/year	SEK/year
Paper	5.5		
Apartment houses		105,000	49,000
Squirrel		189,000	88,000
Glass	7	45,000	21,000
Metals			
Al	150	25,000	11,000
Fe	10,3	14,000	6,000
Textiles	?	-	-
Total	-	378,000	175,000

* from reference and 25 and 28

The financial resultof the Nårab Recycling System, then, can be summarized as follows:

Compared to the landfill:

- o A monetary loss of SEK 165/ton
- o A social benefit of successful recovery
- o A national benefit of saved energy through recycling, with an estimated value of SEK 140- 310 per ton.

Compared to the separation plants:

- o A monetary benefit of at least SEK 140
- o A social benefit of successful recovery
- o A national benefit of saved energy through recycling, with estimated values of SEK 140-310 per ton.

The conclusion must be that source grouping in the Nårab Region has been a success from the cost-benefit balance point of view. Today the source separation system costs the inhabitants of the Nårab region SEK 0.31/week as compared to the alternative cost of landfilling. However, it is not probable that Nårab could have run the landfill for more than a few more years without a supporting system, i.e., source grouping a separation plant or a waste-to-energy plant.

From experience, the cost of those alternatives can be predicted to be at least SEK 150/ton net. Consequently, the monetary benefit of the source grouping system combined with landfilling relative to those alternatives is at least SEK 147/ton. So, in reality, the Nårab Source Separation System saves money for the inhabitants of the region.

Today it is impossible to say what level of costs a source grouping system can tolerate. We know that SEK 117/ton is acceptable /5/, but would SEK 500/ton also be accepted? What is the cost ceiling?

7. DISCUSSION AND CONCLUSIONS

The Nårab Recycling System is a dynamic recycling model based on source separation. The Sanitation company (Nårab) and its contractor (Skånemiljö) are developing the model in an ongoing way. Today our experience is focused on one-family houses and the rural areas, but the model is slowly being adapted to the apartment houses as well. The experience from the Bagaregården test cannot be assumed to be transferable to the Nårab Region. For example, finances are of great importance in the municipalities of Klippan, Perstorp and Örkelljunga. In the pilot test in (Bagaregården) they were not. In Bagaregården there were no refuse chutes, in the Nårab region there are many.

Looking back at reported results from Bagaregården /3,4/ and the Nårab Recycling System /5/ as they are presented in this report we can evaluate and discuss the level of recycling and its influence on society on the basis of a few questions, and draw conclusions indicating the status quo and possible future directions for research.

7.1 What proportion of today's waste stream in the Nårab region is destined for production processes?

Figure 7.1 shows the four steps towards focusing on the effectivity of the reported recycling system in the Nårab region, i.e. the Squirrel collection service.

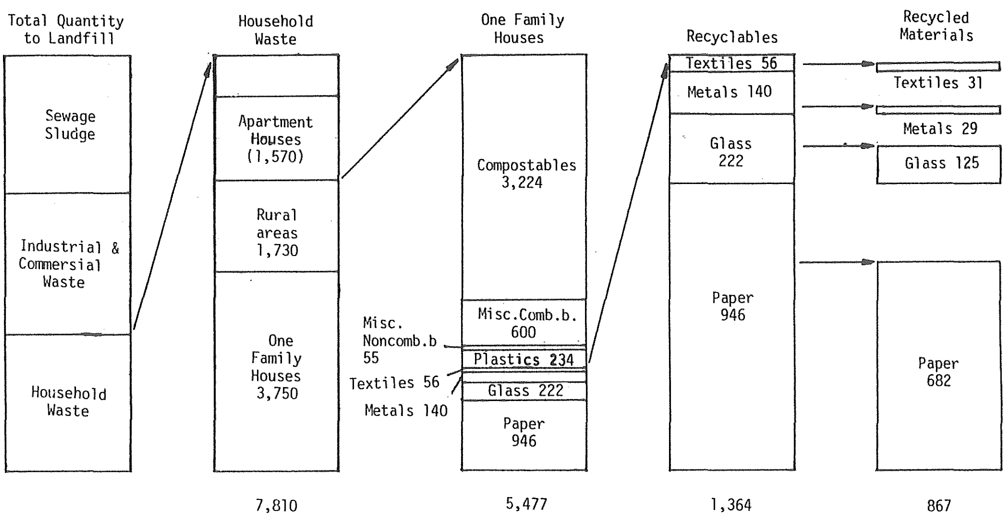

Figure 7.1 Quantities of recycled materials related to total volumes of residuals.

Only 11 % of the total household waste in the region is recycled, and of the total waste from the one-family houses only 16% is recycled. However, the source grouping system only applies to four dry materials: paper, glass, metals, and textiles. Compared to the total quantity of these materials in the one-family houses' waste, as much as 63% is destined for different production systems. The effectiveness of the nationwide paper collection system is 53%. Related to this the Nårab Recycling System is developing sucessfully.

7.2 How many of the possible fractions or materials are destined for recycling?

Today the Nårab Recycling System includes four different materials. They are all dry and easy to handle. Furthermore, there is a market for each of them. Plastics are also dry and easy to handle. There is even a growing market for some kinds. "Plastics", however, are a heterogeneous mixture of many different materials, which can seldom be recovered homogeniously. It is often difficult to distinguish among different kinds of plastics. There are other problems too. Most of the plastic in houshold waste is polyethelyne sheeting, mainly in the form of plastic bags. These are used for packaging the waste, and if they were recycled, other materials would have had to be used for packaging the waste, probably newsprint. This would seriously decrease the paper recovery.

The paper is one of the major parts of the total quantity of residuals. There are two other main parts: compostables and miscellaneous combustibles. Compostables are wet and somewhat problematical to handle, while the miscellaneous combustibles, although they are easy to handle, are difficult to market.

However, the low success rate of the Nårab Recycling System in relation to the total quantity of residuals indicates that other materials must be added to the system if the goal is to limit waste volumes or to increase recycled volumes. From this point of view we cannot deny that the compostables are 50% of the total amount of household residuals from both one-family houses and apartment houses.

7.3 What proportion of the waste stream can we expect to escort to production processes?

The Bagaregården tests added compostables to the three dry recyclables: paper, glass and metals. It was found that at least 50% of the compostables can be collected separately. It was also found that separate collection of compostables, glass and metals can reduce the total amount of waste by 40-45%.

If separate collection of compostables was added to the Nårab Recycling System, and if the same effectiveness was reached as in Bagaregården, the volumes of one-family household waste in the Nårab region would be reduced by about 40-45%.

However, such a development in recycling would require changes in the collection system, since the monthly "Squirrel" collection cannot be used for the compostables, which have to be collected every week in urban areas and at least fortnightly in rural areas.

7.4 What proportion of the population is associated with the Nårab Recycling System?

All the households in one-family houses in the different villages and in rural areas are offered the chance to participate in the source grouping system. All households in apartment houses are offered the opportunity to keep paper separated from the waste.

The Nårab Recycling System is primarily developed for the areas with one-family houses and the rural areas, which comprise 75% of the population and 65% of the households in the geographical area.

Different methods have been used to measure and calculate the degree of participitation. Avfallsgruppen have found that 90% of the families living in one-family houses in the Nårab region keep at least paper apart from the (household) waste. In addition we have found that at least 50% keep glass apart and 40% keeps metals apart from the waste.

7.5 What degree of active participation is found?

The answers to a questionnaire issued in Bagaregården indicate that in a majority of the families it was the women who participated actively the source grouping system. A questionnaire issued in the Nårab Region shows that in 33% of the households all the members of the family share responsibility for the recycling program.

Table 7.1 Who participates in the the recycling program? (Nårab questionnaire, figures in %).

	Size of household					
	Average	1 person	2 persons	3 persons	4 persons	5 persons
All the family	33	5	45	34	22	33
Mother mostly	43	45	38	52	48	35
Father mostly	10	50	10	3	9	5
Mother & Father	14	0	7	12	21	30
Total	100	100	100	101	100	103
Respondents	338	22	122	65	89	40

The questionnaire was answered by 338 participating households containing 1,017 persons, of which 450-500 persons were found to participate in recycling. My conclusion is that about half the involved population participates actively in the source grouping system. The answers also make clear that a majority of the active participants are women, which may be another general reflection of modern Swedish family life (see answers on page 32).

7.6 How far can we reach if we include the apartment houses?

The possibilities of adapting the Nårab recycling system to the apartment houses depend on the possibilities of constructing a collection system that is able to come close to the source, i.e. the households. As we have found, the paper collection system seems to come close enough. Probably the other containers should be placed beside the paper containers, so that together they form a small local recycling center.

The Squirrel is only equipped to empty sacks. Therefore an adaption to the apartment houses involves construction of a new vehicle for emptying bins and dumpsters. That vehicle should probably be able to carry two or more materials separately in order to lower the collection costs.

It is difficult to discuss the degree of recycling from apartment houses, but the results from the Bagaregården tests indicate that the degree of recycling would be at the same level as the presented value from the ongoing Nårab system. This means that the waste would be reduced by 26% in the apartment houses. Carried back to the total amount of households residue this would mean an 18% reduction of waste.

If the compostable fraction were also collected separately the reduction of waste would be more effective. Referring to the results of the Bagaregården tests this type of recycling could bring about a 45% reduction of waste.

When the apartment houses become associated with the recycling system, the whole population will have the opportunity to participate, and probably 80-90% of the households will participate in at least the paper recovery.

7.7 Can the Nårab Recycling System be used on a nationwide basis?

The Nårab system of today has four weak points: it was developed in order to collect the materials close to the houses, it was only designed for areas with one-family houses and rural areas, it is economically feasible only if the collection vehicle works full weeks, and today's collection in rural areas is too expensive.

These weak points place geographical and organizational demands on collection activities. Small municipalities cannot use systems like the Nårab recycling system alone. They have to work jointly in order to have the minimum base of 6,000 to 9,000 households in one-family houses. On the other hand, most small municipalities contain few apartment houses. Consequently, only a few households would be excluded from the recycling system.

Big municipalities and urban areas can use a system like the Nårab system to recycle only a small part of the household residue. In Gothenburg, for example, only 18% of the households are one-family houses. This means that a system like the Nårab recycling system can only serve as complement to a system constructed to recycle household residue from apartment houses.

Only a few Swedish municipalities and regions are similar to each other geographically and organizationally. Therefore it is impossible to try to apply the Nårab Recycling System unreflectedly. In every municipality or region the system must be adapted to local circumstances. The Nårab Recycling System as applied in the Nårab Region is the first adaptation, and today some of the surrounding municipalities are trying to find applications that suit them.

7.8 Further research

Chapter 6.1 states two main justifications for source grouping: recycling and pollution control. Both the Bagaregården tests and the Nårab Recycling System are primarily recycling systems. Furthermore the Nårab system only "picks the raisins out of the cake" (see page 35), while the Bagaregården tests were also intended to contribute to pollution control.

The next step may be to find a system that reduces the waste quantities to a very low level at the same time as the pollution control is put into focus. This would be an experiment in "solving the waste problem", i.e. transforming today's household waste into tomorrow's recyclables, compost, and fuel. The waste quanties may in this way be reduced to a few percent of the quantities of the waste generated today. A test along these lines is planned to begin in around 300-500 households in the municipality of Vaggeryd 1985. Torsten Hultin is leading this project.

Although it makes no claims to completeness or general applicability, it is my hope that the present report is a useful addition to the available literature on waste management technology and the interactions between man and machine in such systems.

In Sweden today there is a increasing interest in source grouping techniques. In addition to this theme there is also a slowly growing understanding of the magnitude of the problems to be faced in using mechanical waste separation techniques. However, the municipalities and their consultants go on acting under the constraints of the waste paradigm, trying to "solve the waste problem" with incineration in waste-to-energy plants.

This is a dangerous situation. We are still trying to solve the waste problem with a lack of knowledge and understanding of the fundamentals of residual products technology. We still have not exactly identified the problems in separation/composting technology. Futhermore, we do not yet know the economic and ecological consequenses of waste incineration or landfill gas production. I cannot see the wisdom in putting more money into techniques about which we know far too little. Why not wait, do futher research and build up the technological development on a scientific basis?

Today there is a study being made by Marie Arehag and myself on the choice of technology/techniques and scale in modern Swedish waste processing. This study is focused on the planning, building and operation of the Swedish separation/composting plants, and we hope that it will provide a better understanding of the nature of the phenomena which have led waste management into using the wrong technology. This study is expected to be completed in 1985. This ought to be followed by the construction of a theory on residual products technology.

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GÖTEBORG 1985