ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF WASTE PACKAGING MANAGEMENT SYSTEMS IN NORWAY:

GENERAL EXPERIENCES

Authors:
Hanne Lerche Raadal
Cecilia Askham
Ole Jørgen Hanssen
Lars von Krogh

Oestfold Research Foundation
OR 27.01
Fredrikstad October 2001

REPORT OVERVIEW

Reportnumber: OR 27.01

ISBN nr: 82-7520-429-1
ISSN nr: 0803-6659

Report:

Reportheading:
Environmental Life Cycle Assessment of Waste Packaging Management Systems in Norway: General Experiences

Author(s):
Hanne Lerche Raadal
Cecilia Askham
Ole Jørgen Hanssen
Lars von Krogh

Projectnumber:
222930

Projectheading:
Waste Packacging Management Systems in Norway: General Experiences

Report employer: Plastretur AS and Returkartong AS
Employer reference: Peter Sundt and Sveinar Kildal

Resymè:

This report summarises the findings and conclusions from various work completed by Østfold Research Foundation between 1999 and august 2001. It focuses on the waste management system in the Drammen region before and after the introduction of a waste sorting system. Four waste fractions have been scrutinised: plastic, carton packaging, drink cartons and corrugated cardboard. The analyses conclude that material recycling is the most environmentally beneficial way to manage these four fractions and that the environmental benefits increase with higher rates of material recycling.

The authors argue that dynamic and holistic perspectives are necessary in order to best optimise waste management systems, both in terms of environmental effectiveness and socio-economic effectiveness. Industrial ecology is put forward as a realistic approach in order to meet the future challenges that the current narrow-minded and shortsighted policies regarding waste treatment practices are unable to do.

Keywords:
- Waste Recycling Systems
- Material recycling
- Environmental effectiveness
- Industrial ecology

Officiality:

This side: Open
This report: Open

Total number of pages: 18

.

Date: 17.10.01

Ole Jørgen Hanssen
Projectleader

Mie Vold
Director of Institute

CONTENTS

EXCECUTIVE SUMMARY

This report summarises the findings and conclusions from various work completed by Østfold Research Foundation between 1999 and august 2001. It focuses on the waste management system in the Drammen region before and after the introduction of a waste sorting system. Four waste fractions have been scrutinised: plastic, carton packaging, drink cartons and corrugated cardboard. The analyses conclude that material recycling is the most environmentally beneficial way to manage these four fractions and that the environmental benefits increase with higher rates of material recycling.

The authors argue that dynamic and holistic perspectives are necessary in order to best optimise waste management systems, both in terms of environmental effectiveness and socio-economic effectiveness. Industrial ecology is put forward as a realistic approach in order to meet the future challenges that the current narrow-minded and shortsighted policies regarding waste treatment practices are unable to do.

1 BACKGROUND

Østfold Research Foundation (STØ) has assessed a number of recycling systems in Norway on behalf of the National Recycling Schemes. The Life Cycle Assessment method has been used as a basis for the environmental assessments. The same method and data tool has also been used for socio-economic studies. The analyses have been undertaken with reference to the Drammen region in the East of Norway. The focus has been on the following waste fractions:

- Plastic packaging waste.
- Drink cartons.
- Carton packaging.
- Corrugated cardboard.

2 THE AIM OF THIS STUDY

The aim of this report is to make the main findings from the studies listed above available for the international community.

Three main reasons for undertaking the studies were:

- Input to self-evaluation by the National Recycle Schemes, in order to improve the efficiency of waste recycling systems.
- Input to discussions with authorities in their evaluation of waste management practices.
- Input to general discussions.

3 METHODOLOGICAL ASPECTS

The study is based upon the life cycle analysis (LCA) methodology, as described in the ISO-standards 14040-43. The analysis has been carried out with the aid of the LCA Inventory Tool computer software. The LCA methodology is adapted to each particular study according to their objectives.

3.1 LCA in general

An LCA of a product is defined as a systematic mapping and assessment of environmental and resource impacts throughout the entire life cycle of the product. The LCA methodology includes all processes and activities that are part of a product system, and thus contribute to achieving the function or functions that the product system shall fulfil.

Three central points describe an LCA:

- The focus is on the whole technical system needed to produce, use, and dispose of a product (system analysis), and not just on the product itself.
- The analysis is of the entire material cycle in the value chain of a product, and not only on one single operation or process-stage of a product (e.g. raw material refining).
- A number of relevant environmental and health impacts for the entire system are analysed, not just on one single environmental aspect (e.g. emissions of solvents or dust).

LCA typically applies to product systems, and is not primarily designed to handle material flows or waste management systems as such. However, there are several advantages to be gained by using LCA on such systems, in combination with Material Flow Analyses (MFA). MFA as such typically focuses on material flows within a defined region, assessing the input and output flows as materials are transported and distributed through and througout the region. MFA does however not consider total environmental impacts related to the material flows, which can be done in combination with LCA. LCA focuses on a given Functional Unit (FU), which is crucial in comparison between different systems. For waste management systems, it is important to measure any loss or increase of efficiency relative to a reference system.

The functional unit (FU) in these studies is *treatment of one tonne or kg of the specific waste (plastic, drink cartons, carton packaging) which ends up as household waste*, except for corrugated cardboard where it is *one kg corrugated cardboard delivered to material recycling*.

By acknowledging the strengths and weaknesses of both methods, the combination of LCA and MFA is thus found very applicable for our studies of waste management systems.

Throughout this report where percentage (%) is stated, either in the text or in figures, the meaning is *weight-percent*, if nothing else is stated.

3.2 Carrying out the studies

The project has been carried out using the Drammen region as an example. This has been done because the local authorities in this region have been among the first local authorities in Norway to establish collection points for plastic packaging waste. The Drammen region consists of nine municipalities: Lier, Drammen, Svelvik, Nedre Eiker, Øvre Eiker, Modum, Hurum, Røyken and Sande. There are approximately 160 000 inhabitants in the region.

In 1997/98 a new waste management system was initiated in the Drammen region. The system was divided into three parts: households, designated collection points, and waste sorting facilities. In the households the following fractions were sorted: paper, cardboard, drink cartons, wet organic waste and residual waste. The following fractions could be brought to the designated collection points: clear and coloured glass, metals, plastic packaging waste and textiles. The waste sorting facilities could receive the same fractions in addition to paper and cardboard, wood, refrigerants, special waste and residual waste.

Two main scenarios are analysed for each fraction: one scenario is the waste management system before the sorting system was introduced (when the waste was deposited on a landfill). The other scenario shows a balance between material recycling and energy recovery. Diagrams are included in this report that shows both scenarios in the same figure, for easy comparison. Further details regarding these scenarios are described below in the sections of the report that are dedicated to the relevant waste fractions.

The figure below shows the system analysed for plastic packaging from households as an example.

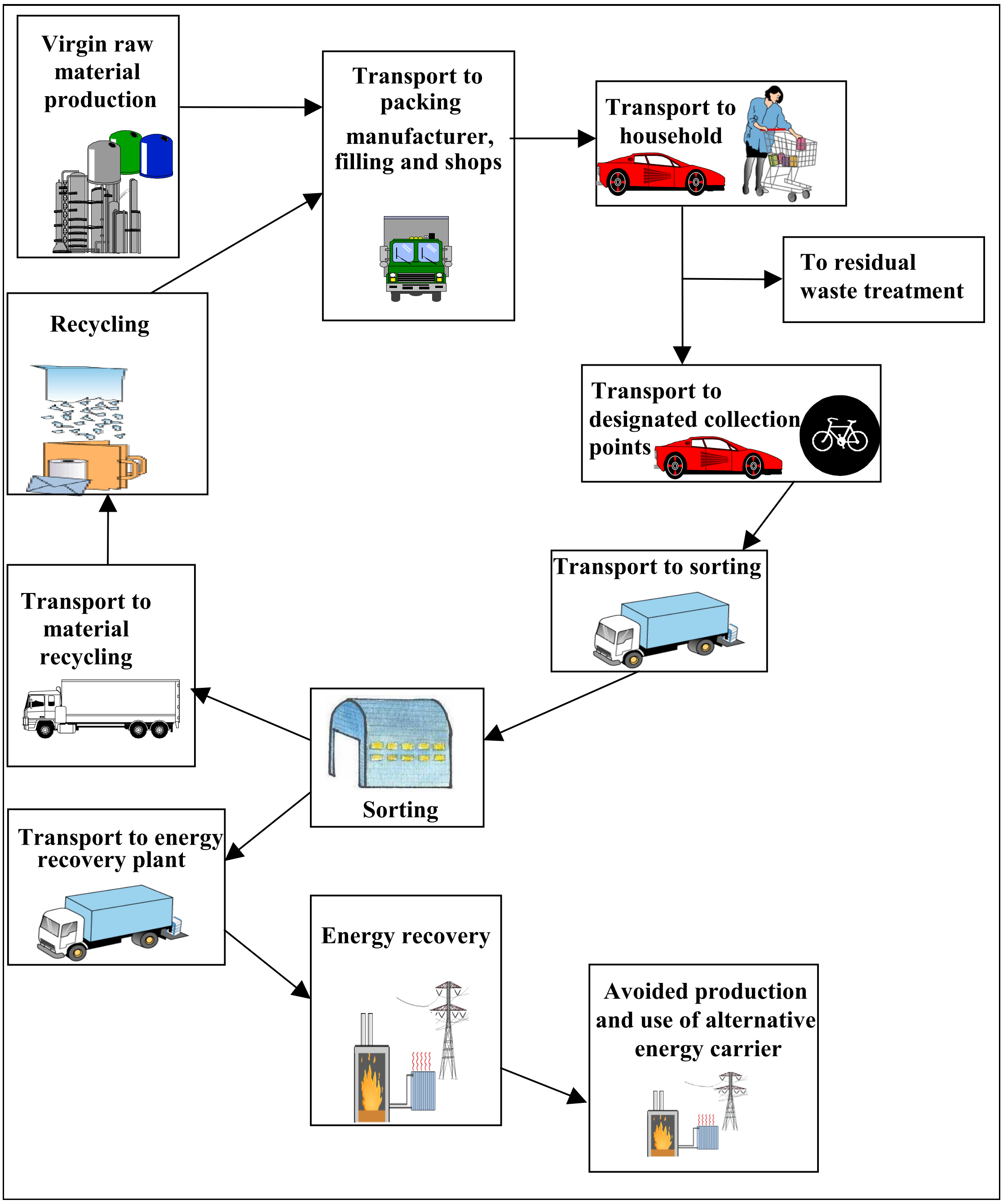

Figure 1: All the steps included in the life cycle assessment of a material packaging waste management 'bring system' in the Drammen region.

All of the environmental effects that are expected to be significant and can be quantified in a life cycle assessment have been included in the analyses. However, the results presented focus upon the following environmental impacts:

- Primary energy consumption.
- Global warming potential.
- Acidification.
- Eutrophication.
- Photo-oxidant formation.

3.3 Specific preconditions

There are a number of specific preconditions that apply to LCA studies of waste management systems:

- Accounts of energy and materials are jointly considered, and the system analyses focus on the waste material distribution to recycling, energy recovery and landfill.
- Analyses of recycling systems credit the substitution of virgin raw material by the recycled material.
- Analyses of energy recovery systems credit the substitution of another energy carrier.
- Household waste sorting and cleaning is not considered to contribute to any economic or environmental costs.
- In all systems, a functional unit (FU) is used as a reference flow through the system. In most systems the FU is set to 1000 kgs of waste generated in households.
- If possible, analyses use average data from specific regions and a specific year.
- Comparisons are made between the basis year and a year with the new system in use.
- Instead of allocation, system boundaries are enlarged when necessary and relevant.

3.4 Effects of increased recycling

When the fraction of material that is recycled in a waste management system is high, then the material has the potential to be recycled and used many times. The methodology used for taking this into account is described in detail in Askham Nyland et al. 2001. The figure below illustrates the effect by showing how the amount of material function obtained from 1 kg of virgin material input can be increased dramatically by increasing recycling rates:

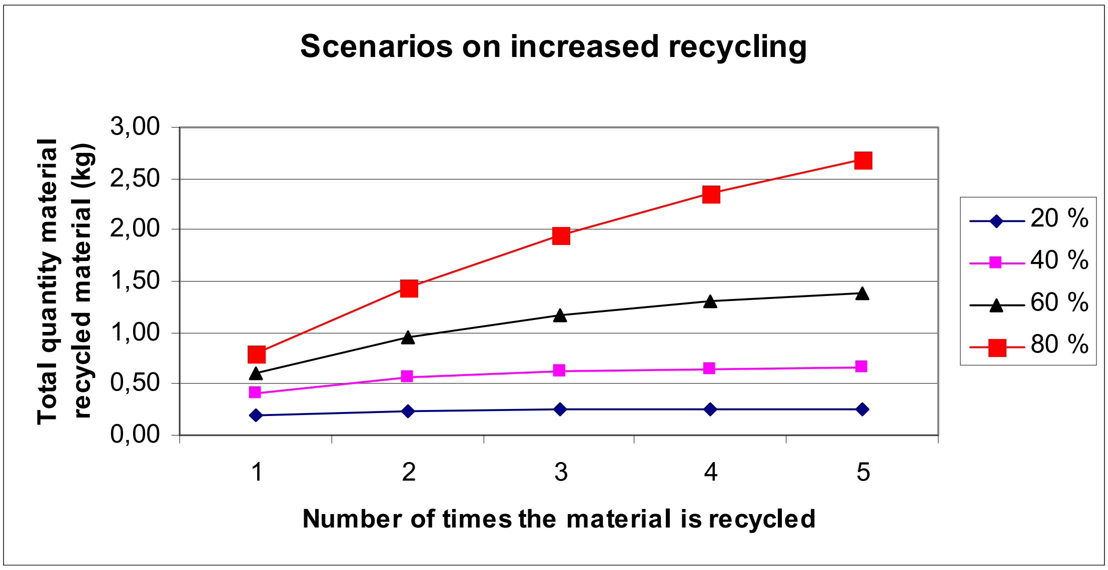

Figure 2: Total quantity of material function (kg) for 1 kg virgin material input into the system. The figure shows the quantitative development at different collection rates as a function of how many times the material is recycled.

The figure above shows that in systems where more of the material that is put into the system is material recycled (up to 80%), then, by recycling several times, it is possible to utilise this waste material up to 2-3 times. In other words: bigger savings in virgin raw material (and less harm to the environment) are possible if recycling systems take into account the possibility of repeated recycling.

For the analyses on plastic, further recycling loops are not included because relatively low quantities of plastic are sorted out to be used in material recycling. As we see from the figure above, when only 26 % of the material is recycled, the effect is poor. However, at higher recycling rates, the effect increases. This is reflected in the analyses of drink cartons, carton packaging and corrugated cardboard.

4 RESULTS

The results from the main reports are presented for different environmental impact categories. However, in this report, only the figures for global warming potential are presented in order to illustrate the trends in the overall results, as the different impact categories show relatively similar trends.

4.1 Plastics

Before the system for plastic sorting in the Drammen region was introduced, plastic packaging was collected together with residual waste and deposited on a landfill. In 1999, about a year after the commencement of the household sorting system, approximately 26 % of the household plastic was captured in the collection system to be recycled (5%) or energy recovered (21%). 74% was still being deposited on a landfill. The figure below shows a simple flow chart for the waste management system for plastic packaging in the Drammen region in 1999:

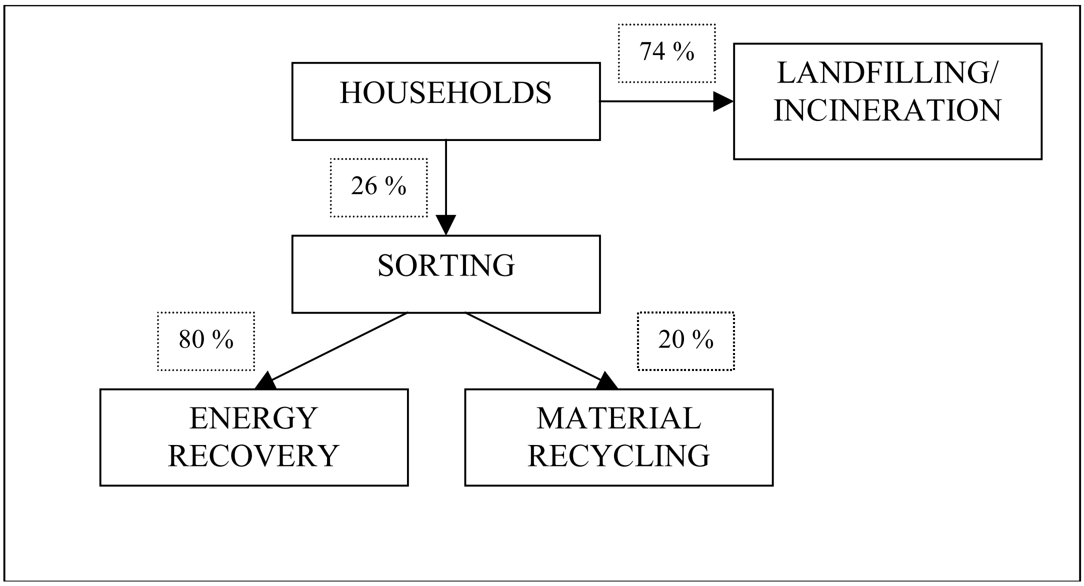

Figure 3: Flow chart for the plastic packaging waste management system in 1999 in the Drammen region.

In the graphs below the environmental impacts are presented for the following life cycle steps:

Transport	All transportation undertaken within the waste management life cycle.
Waste management	Material recycling, energy recovery, sorting and landfill.
Avoided oil	Extraction, processing and use of oil, equivalent to the energy content which is generated from the energy recovery of plastics. Credits are given for replacing this amount of oil.
Avoided material	Extraction, processing and transport of virgin raw material for the packaging producer, equivalent to the quantity of plastic being recycled. Credits are given for replacing this amount of virgin raw material.
Total	Sum of all environmental impacts (positive and negative) for all life cycle steps for the two systems = total net environmental benefit.

The figure below shows the global warming potential for the reference situation (1996, landfill) compared to the situation in 1999 (plastic packaging waste collection system in use).

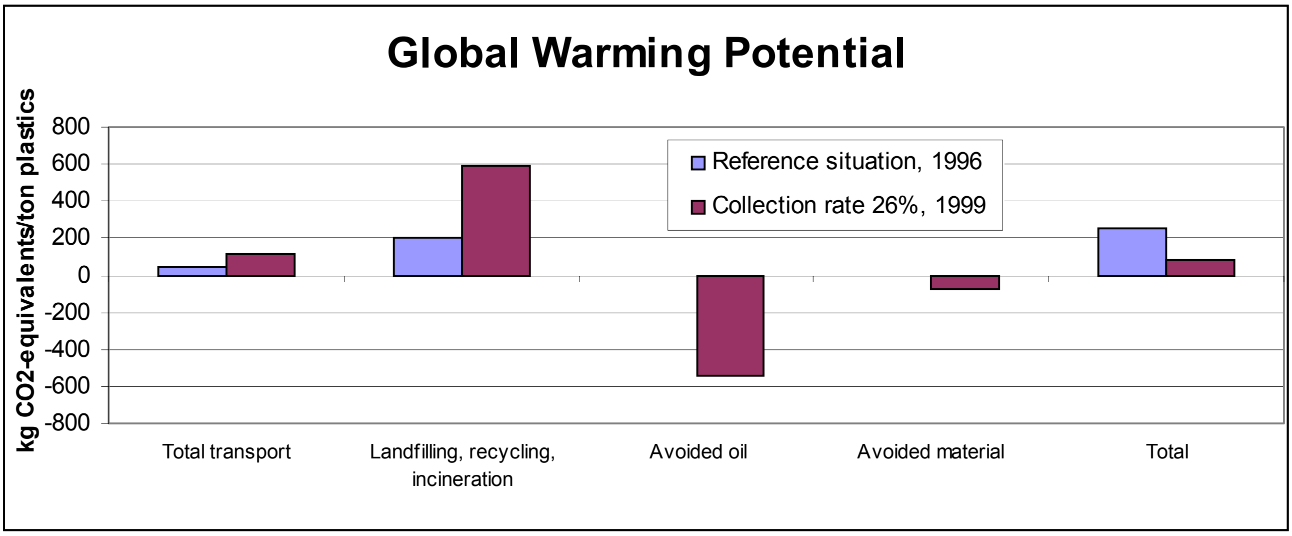

Figure 4: Global warming potential for the reference situation and the situation in 1999 (plastic packaging waste collection system in use).

The figure above shows that the system with a relatively small collection rate (26%) is the better system, emitting only 1/3 of CO_2-eqivalents per ton plastic compared to the reference situation.

In order to differentiate between different end treatment methods, three comparable scenarios for landfill, energy recovery and material recycling of plastic packaging waste are shown below:

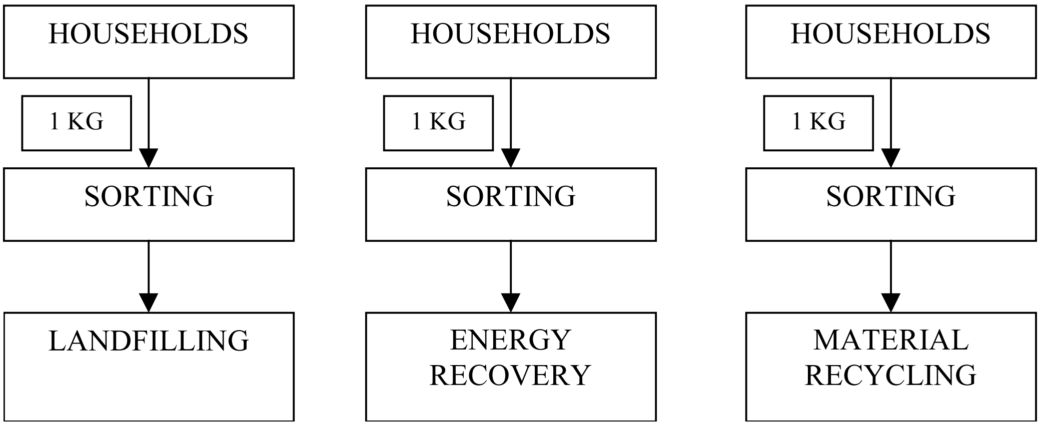

Figure 5 below compares the global warming potential for depositing 1 ton of plastic packaging waste on a landfill compared to energy recovery or recycling of the same amount of plastic packaging waste.

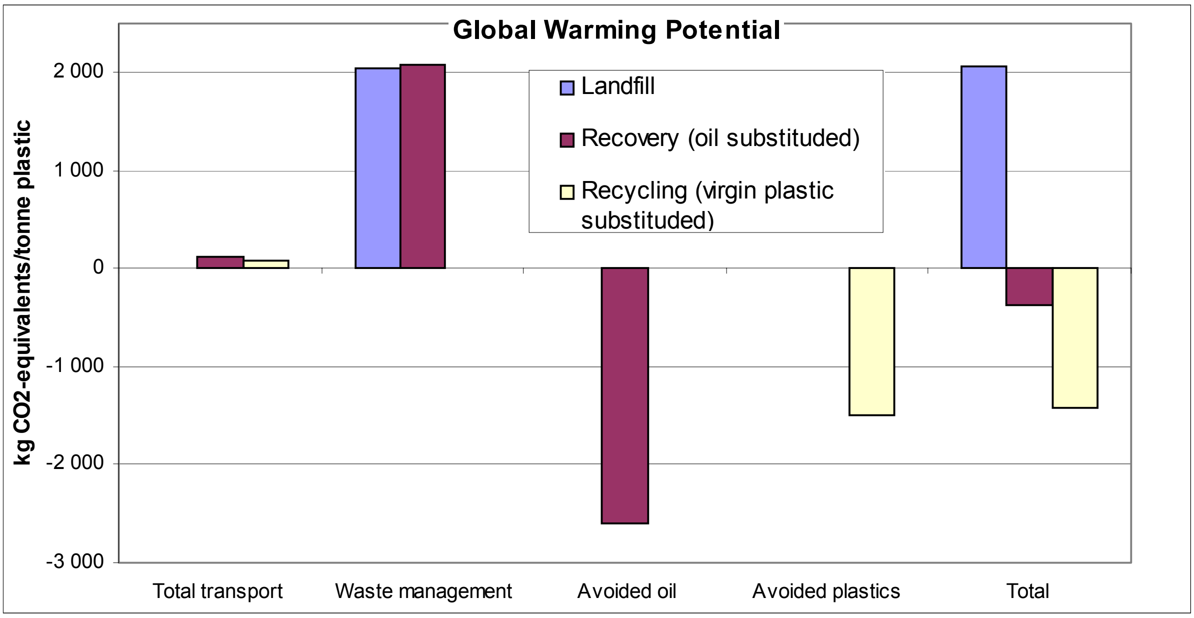

Figure 5: Global warming potential for 1 tonne of plastic packaging waste from households in the Drammen region where the plastic is either deposited on a landfill, sent to energy recovery or recycled.

The results from the study show that the environmental effectiveness of the plastic waste treatment system in the Drammen region increases with increasing degree of material recycling. This applies to both increasing the amount of plastic waste that enters the collection system and to increasing the percent of waste collected that goes to recycling as opposed to energy recovery.

The analyses show that the contribution from transportation to any of the impact categories analysed is insignificant. The two transportation steps from the households to the collection points and from the collection points to sorting are the least environmentally effective of all the transport steps in the waste management life cycle.

One of the main conclusions from the analysis is that increased material recycling results in lower environmental impacts per ton waste material generated. Thus, throughout the entire recycle loop one should aim at recycling as much of the plastic packaging waste as possible.

4.2 Carton packaging and drink cartons

Analyses of carton packaging and drink cartons consider household waste only. The share of the recyclable materials that is not separated from the mixed waste in the households is assumed to be treated together with the residual waste (landfill). The situation in 1999 (1999 case) shows that 69% of drink cartons were separated out from normal household waste in the households and collected for material recycling. However, the corresponding figure for carton packaging was 59%. Unlike the collection system for plastics (‘bring system’, where plastic is brought to collection points), the carton packaging and drink cartons are collected from the households in a kerbside system.

It is assumed that the material is recycled 5 times, followed by energy recovery of the remaining material. Figure 6 shows that recycling carton packaging 5 times has the most beneficial net effect on global warming. This presumes 59% collection rate, and that the material that is not material recycled is incinerated with energy recovery.

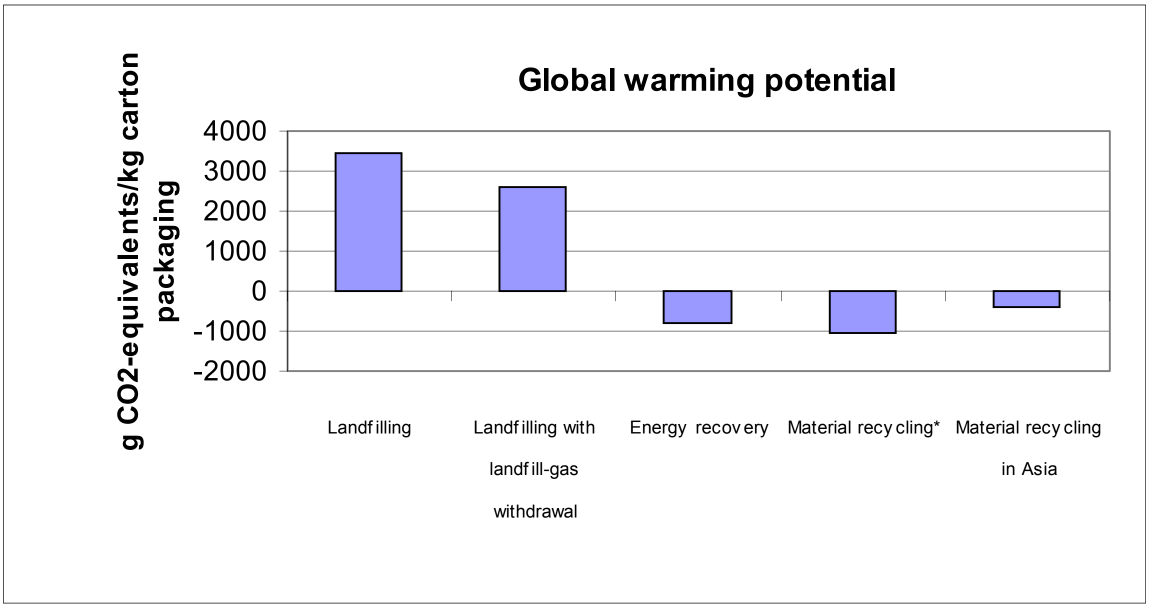

Figure 6: Global warming potential for different waste treatment scenarios (including the complete lifecycle involved in each scenario) for carton packaging. *

Exporting the carton packaging waste to Asia is a significantly better option when compared to landfill in Norway.

As with plastic waste recycling, there is a loss of environmental effectiveness when:

- Too little material is collected.

* For the recycling case: the material is recycled 5 times followed by energy recovery of the remaining material. All that is not material recycled is assumed to go to energy recovery.

- The share of waste that is not sorted is deposited on a landfill instead of being incinerated with energy recovery.

The environmental benefits increase for all impact categories when the amount of material collected increases. For a collection rate of 80% of the available carton packaging, primary energy savings are almost doubled, when compared to a collection rate of 59% (1999 case).

4.3 Corrugated cardboard

Corrugated cardboard has been analysed on the same terms as the previously described fractions. However, in the analyses of corrugated cardboard the main waste generator is industry (89%). Households only account for about 11% of the corrugated cardboard collected in the analysed system. Corrugated cardboard imported from Sweden is also included in the analysis. This amounts to about 18% of the total share of corrugated cardboard that is recycled. The 1999 case shows that 94% of the collected fibres are recycled, and only small fractions are deposited on a landfill or incinerated.

The environmental impacts are presented for the following steps in the lifecycle of corrugated cardboard:

Transport	All transportation undertaken within the waste management life cycle.
Sorting and material recycling	Environmental impacts from sorting and material recycling processes, including waste treatment.
100% energy recovery	Environmental impacts from the energy recovery process (when all material is incinerated). Credits are given for substituted energy (oil) and its potential environmental impacts from extraction and use.
Avoided virgin raw material	Credits given for avoided virgin raw material production.
Energy recovery of recycled material	Environmental impacts related to energy recovery of recycled material in the system. Credits are given for substituted energy (including extraction, processing and use of this energy carrier).
Total	Sum of all environmental impacts (positive and negative) for all lifecycle steps for the three systems = total net environmental benefit.

Figure 8, below, shows the contributions to global warming potential for the system as it was in 1999 (94% recycled) compared with a system where all the cardboard goes to energy recovery.

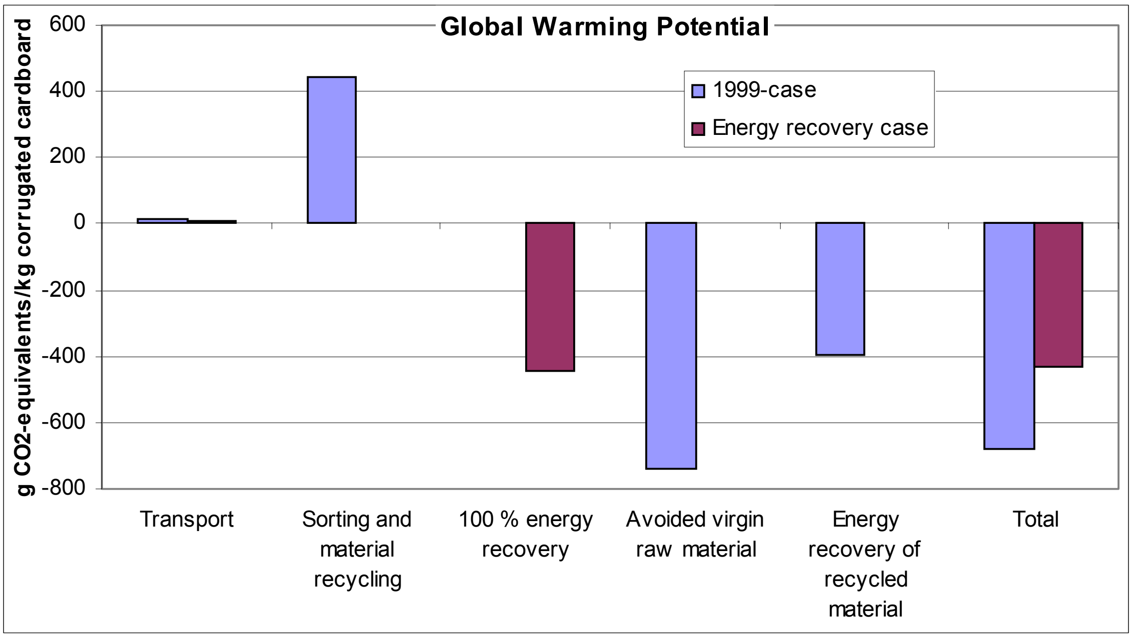

Figure 8: Global warming potential for corrugated cardboard recycled once with subsequent energy recovery compared with 100 % energy recovery.

The figure shows that the recycling system has greater environmental benefits, shown by the larger credits for global warming potential.

The analyses performed show that both increased number of recycling loops (i.e. the number of times a corrugated board is recycled) and increased collection rates give an additional increase in the net environmental benefit.

5 THE MOST SENSITIVE ASSUMPTIONS

5.1 Energy substitution

All analyses with scenarios involving energy recovery credit the substitution of an energy carrier (oil, or energy mixes with oil as a large component). This means that the emissions from extracting, processing and generation of energy have been subtracted in the calculations of environmental effectiveness, and thus represent a benefit for the system as a whole. However, the location of an energy recovery plant is crucial in terms of deciding which energy carrier to substitute in order to replace the most energy- and thus achieve the highest environmental efficiency. The following priority hierarchy should be considered for waste incineration with energy recovery:

1. Coal, for example in cement production.
2. Oil used in industrial processes.
3. Oil used in heating of houses, offices, etc.

Two or more of these heat requirements should be fulfilled in the same system in order to take full advantage of the available energy. For example, an energy intensive industry can use the heat first, and subsequently distribute the lower grade heat to industries or buildings that only require ”second hand” heat. As long as the alternative energy carriers are fossil fuels, or an energ mix containing a high share of fossil fuels, the analyses in the Drammen region show that such an energy policy will be the most beneficial to the environment.

5.2 Material substitution

All analyses with scenarios involving material recycling credit the substitution of virgin raw materials. This means that the emissions from extraction and processing (up to the same step in the product life cycle as where the recycled material replaces virgin raw material) have been subtracted in the analyses. As with energy replacement, this also represents a great benefit (depending on the virgin raw material processing requirements) with regards to environmental effectiveness for the total system.

5.3 Transport is not significant

As shown in the figures above, transport is of very little importance to the total environmental burdens of the systems. The transport step that contributes most to the total burdens, is the step from the household to the collection point. Where the recycling plant is located has therefore less meaning than how the local collection points are located, and to what extent the local inhabitants deliver waste in combination with other errands. For kerbside collection schemes, how the collection from households is organised is also more significant than where the recycling plant is located.

6 INDUSTRIAL ECOLOGY PERSPECTIVE FOR WASTE MANAGEMENT

The methodology of lifecycle analysis has many advantages that can be utilised for waste management system analyses. The main point is that the method aims to take a holistic approach. For waste management systems, this means that one or more fractions can be analysed in the same system. The analysis includes every step from waste generation to when the waste is finally treated. The analysis also includes all possible treatment steps, e.g. material recycling, energy recovery, incineration without energy recovery and landfill. All quantifiable emissions from each of these treatment processes can be included in the analysis. LCA analyses indicate which treatment processes and combinations (distribution of waste fractions and amounts) are the most environmentally beneficial. Sensitivity analyses can also be used to show how robust the conclusions are. Holistic analyses also include the benefits from replacing virgin raw material and the benefits from substituting a particular energy carrier, or mixture of energy carriers.

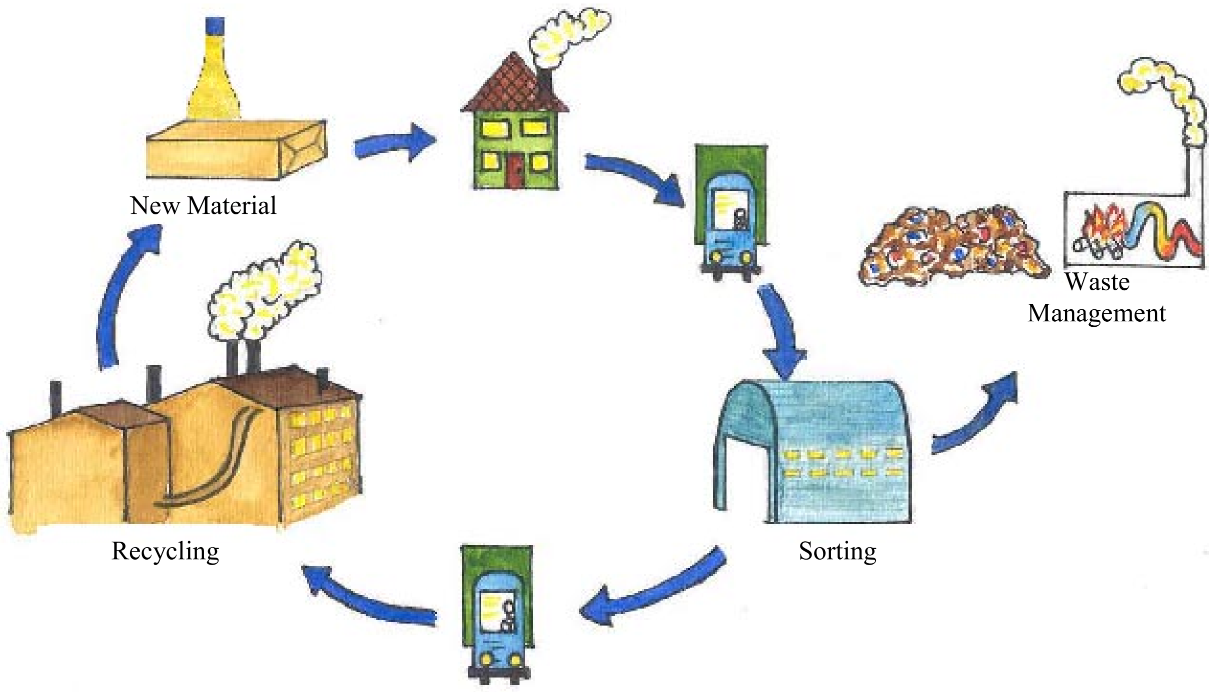

Figure 8: Illustration of the steps considered in holistic waste management analyses of plastic, carton packaging, drink cartons and corrugated cardboard.

7 CONCLUSIONS

This report has focused on five major aspects of analysis of waste treatment options:

1. When waste is created, material recycling is the most beneficial waste treatment option with regards to minimising harmful discharges to the environment.
2. Waste resources that cannot be recycled should go to energy recovery. The decision about which energy carrier(s) is (are) substituted should be made carefully.
3. When considering the complete lifecycle of a waste management system, transport is of little environmental importance.
4. An industrial ecology approach should be applied to such systems analyses.
5. Socio-economic analyses should be based on a holistic systems approach.

Prevailing national waste management policies in Norway pay little or no attention to the advantage of an industrial ecological perspective in waste management. Instead, Norwegian authorities seem to embrace waste incineration, without utilising the waste as a raw material for new production. This recycled material can eventually be utilised for its energy content after several recycling loops.

According to one frequently cited study (Bruvoll), which is based on traditional cost-benefit analyses, waste management in Norway is better off if more waste is incinerated. STØ is of the opinion that this perspective is static and not very visionary. In addition the Bruvoll report contains some very questionable assumptions, like putting an artificial (high) cost on household waste sorting. The analysis does not credit the avoidance of virgin raw material production either. Such a study fails to see the potential socio-economic benefits that waste resources can indeed generate, if industrial ecological principles are followed. Industrial ecology focuses on the dynamic interrelationships between different actors in a system, just like nature's own symbiotic mechanisms. Systems including higher degrees of waste sorting, material recycling several times and subsequent energy recovery unambiguously show great environmental benefits.

However, nature is hard to imitate. Human made systems should be allowed a running-in period where, as long as potential benefits can be indicated through analysed scenarios, the system should be taken seriously rather than set aside because of some snapshot assessments. STØ's analyses also show that the socio-economic effectiveness of systems with a high degree of material recycling can be higher than systems without recycling.

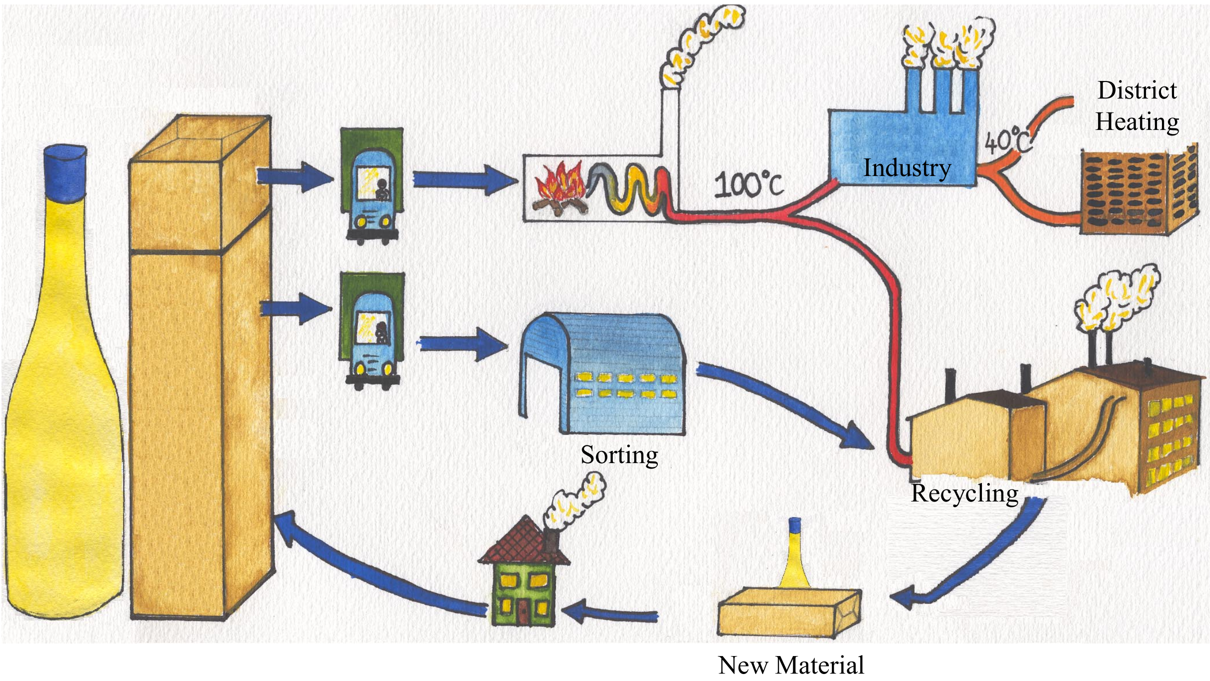

Figure 9: An optimal (and realistic) waste management system for plastic, carton packaging, drink cartons and corrugated cardboard.

REFERENCES

Askham, C., Raadal H. L., Hanssen, O. J., *Analyse av miljøeffektivitet ved innsamling og gjenvinning av drikkekartonger, kartongemballasje og bølgepapp* (Analysis of the environmental effectiveness of collection and recycling of drink cartons, carton packaging and corrugated cardboard), Oestfold Research Foundation, OR 24.00, 2000.

Askham, C., von Krogh L., Hanssen, O. J., *Tilleggssimuleringer og datagrunnlag for en kortversjon av OR 24.00* (Additional simulations and data for a short version of OR24.00) Oestfold Research Foundation, OR 07.01, 2001.

Askham, C., von Krogh L., Hanssen, O. J., *Det Nytter!* (It is beneficial! A 4-page brochure on the environmental benefits of recycling) Oestfold Research Foundation, 2001.

Askham Nyland C, Raadal H L, Hanssen O J., Modahl I S, *How LCA is Used for Assessment of Waste Management Systems, Including a Model Allowing for Recycling of Materials Several Times.* Article submitted for publication in The International Journal of LCA, Oestfold Research Foundation, 2001.

Bruvoll A: *The Costs of Alternative Policies for Paper and Plastic Waste*, Statistics Norway 98/2

Raadal, H. L., Hanssen, O. J., Rymoen, E., *Gjenvinning av plast i Drammensregionen. Vurdering av miljø- og ressurseffektivitet i innsamling og gjenvinning av plastemballasjeavfall* (Recycling of plastic in the Drammen region. Assessment of the environmental and resource efficiency of the collection and recycling of plastic packaging waste), Oestfold Research Foundation, OR 17.99, 1999.

Raadal, H. L., Hanssen, O. J.: *Gjenvinning av plast i Drammensregionen. Vurdering av deponering, forbrenning og gjenvinning av plastemballasjeavfall* (Recycling of plastic in the Drammen region. Assessment of landfill, energy recovery and recycling of plastic packaging waste), Oestfold Research Foundation, OR45.99, 1999.

Raadal, H. L., von Krogh L., Askham Nyland C, Hanssen, O. J.,: M*iljø- og samfunnsøkonomisk vurdering av håndtering av plastemballasje avfall fra husholdninger i hias- og drammensregionene* (Environmental and socioeconomic analysis of the treatment of waste from households in the Hias and Drammen regions), Oestfold Research Foundation, 2001.

ISO 14040:1997. Environmental management - Life cycle assessment - principles and framework. International Organization for Standardization. Geneva, Switzerland, 1997.

ISO/DIS 14042:1999. Environmental management - Life cycle assessment - Life cycle impact assessment. International Organization for Standardization. Geneva, Switzerland, 1999.

ISO/DIS 14043:1999. Environmental management - Life cycle assessment - Life cycle interpretation. International Organization for Standardization. Geneva, Switzerland, 1999