Comparison of Feedstock Recycling and Alternative Treatment Methods for Household Plastic Waste

ENGLISH SUMMARY REPORT

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REPORT OVERVIEW

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Summary:
Life Cycle Assessment methodology has been used in order to obtain a rough comparison of the environmental benefits of feedstock recycling with alternative treatment methods for plastic waste from households in Norway.

The ranking between the different alternatives varies according to which environmental impact is assessed. The exception to this is incineration in a waste incinerator, which gives the least environmental benefits for all of the environmental impacts assessed. Feedstock recycling gives a marginally greater environmental benefit than a high rate of mechanical recycling (49%) for global warming potential. However, for the other environmental impact categories analysed (acidification, eutrophication and energy use), feedstock recycling has a clearly worse environmental profile than both a high rate (49%) and a lower rate (21%) of mechanical recycling. Industrial energy recovery as a replacement for coal gives the greatest environmental benefit for the impact categories acidification and eutrophication.

The most important assumptions used in the analyses of the different treatment methods are described. However, if the results are to be important for strategy work to find the most environmentally and economically beneficial methods for recycling plastic, it is recommended that follow-up studies are carried out in order to more thoroughly analyse the systems and test the most sensitive assumptions and parameters. This is particularly relevant for the assumption that industrial energy recovery from plastic in cement production replaces coal, as well as quality control of data and assumptions used for the analysis of feedstock recycling in Germany.

With this background, as well as the EU proposal that feedstock recycling shall not be counted as material recycling, it is recommended that a more comprehensive study is carried out. This can be the basis for important input to both strategic decisions for Plastretur and the EU directive.

Keywords:
- Plastic packaging waste
- Feedstock Recycling
- Mechanical Recycling
- Energy Recovery

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Contents

1 Background and Aims

Plastretur has an agreement to send about 3000 tonnes of plastic packaging waste from Norway to Germany for feedstock recycling, for a test period. The plastic is broken down to methanol as a new raw material. Electricity is also produced in the process. Plastretur therefore wish to assess the environmental benefits of this type of recycling system, and compare these with the results from earlier analyses of the waste treatment of plastic packaging waste.

Aim
To carry out a rough comparison of the environmental benefits of different waste treatment methods for plastic packaging waste from households.

2 Methodology

Life cycle assessments (LCAs) have been carried out for the different treatment methods. These assessments entail the gathering of data for emissions to air, water and soil associated with the different activities for each system and calculating potential environmental impacts associated with these. These data and calculations are the basis for calculation of the nett environmental benefits for each system.

3 Description of the Different Alternatives

The alternatives describe different waste treatment solutions for plastic packaging waste, beginning with the generation of 1 tonne of plastic packaging waste in households. The functional unit for the systems analysed is therefore:
Waste treatment of 1 tonne plastic packaging waste arising in households in Norway.

The following treatment alternatives for plastic packaging waste are assessed and compared:

- **Incineration:** No source sorting, plastic is collected together with other household waste and is burnt in a waste incinerator with energy recovery.
- **Mechanical 21%:** source sorting with a collection system, 61% collection rate and 21% mechanical recycling rate. The plastic that is not recycled mechanically (40%), is assumed to be sent to energy recovery in a cement kiln in Aalborg in Denmark. The plastic that is not source sorted (39%), is incinerated together with the other household waste.
- **Mechanical 49%:** source sorting with a collection system, 61% collection rate and 49% mechanical recycling rate (approaching the maximum potential for mechanical recycling). The plastic that is not recycled mechanically (12%), is assumed to be sent to energy recovery in a cement kiln in Aalborg in Denmark. The plastic that is not source sorted (39%), is incinerated together with the other household waste.

- **Feedstock 61%:** source sorting with a collection system, 61% collection rate with transport to Germany for feedstock recycling at SVZ[1]. The plastic that is not source sorted (39%), is incinerated together with other household waste.
- **Energy 61%:** source sorting with a collection system, 61% collection rate with transport to Denmark for energy recovery in a cement kiln in Aalborg in Denmark. The plastic that is not source sorted (39%), is incinerated together with other household waste.

The collection rate is calculated as follows:

$$\frac{\text{Amount of collected plastic packaging waste per person and year (kg)}}{\text{Total amount of plastic packaging waste generated per person and year (kg)}} = \textit{collection rate}$$

Data for the total amount of plastic packaging waste generated per person and year is provided by Plastretur: 13,4 kg per person and year (basis 1998).

The amount of collected plastic packaging waste for all of the alternatives, except for ’Incineration’, is calculated based on average data from the Hamar and Molde regions in Norway (8,2 kg/person and year, equivalent to 61% collection rate) in 2002.

For the ’Mechanical 21%’ alternative, the share of collected plastic that goes to mechanical recycling and the share to energy recovery, are calculated from measurements carried out at the sorting facility (SSR) in the summer of 2002 [5].

For the ’Mechanical 49%’ alternative, it is assumed that a larger percentage of the collected plastic goes to mechanical recycling from sorting.

For the alternatives ’Feedstock 61%’ and Energy 61%’, it is assumed that there is no sorting of the collected plastic, which is transported directly to the relevant facilities for feedstock recycling in Germany and energy recovery in Denmark.

The five alternatives that are compared in this report are described with the help of diagrams (figures 1-5) below.

[1] Skundärrohstoff-Verwertungszentrum, Spreetal, Germany

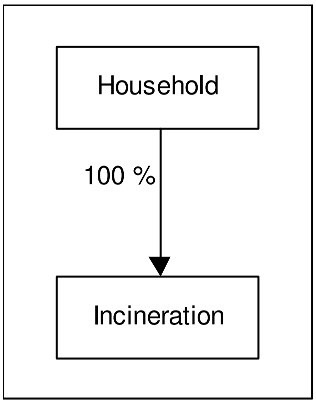

Figure 1:*'Incineration': all plastic follows the other household waste to incineration with energy recovery.*

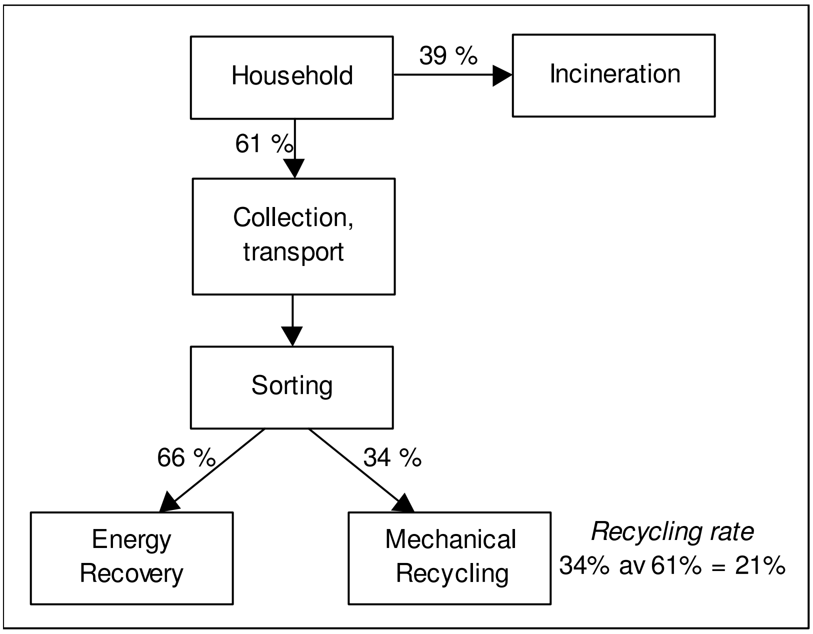

Figure 2:*'Mechanical 21%': source sorting with 61% collection rate and 21% material recycling rate.*

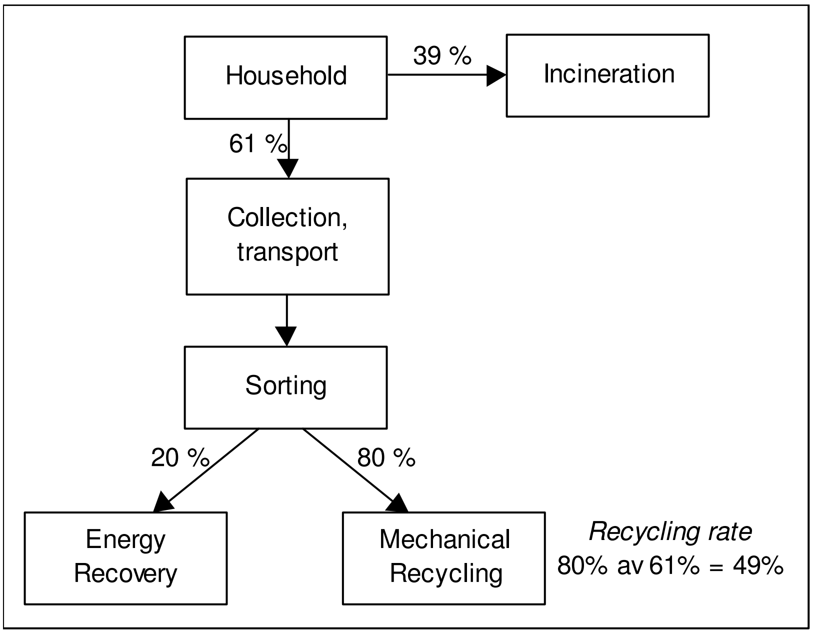

***Figure 3:**’Mechanical 49%’: source sorting with 61% collection rate and 49% material recycling rate.*

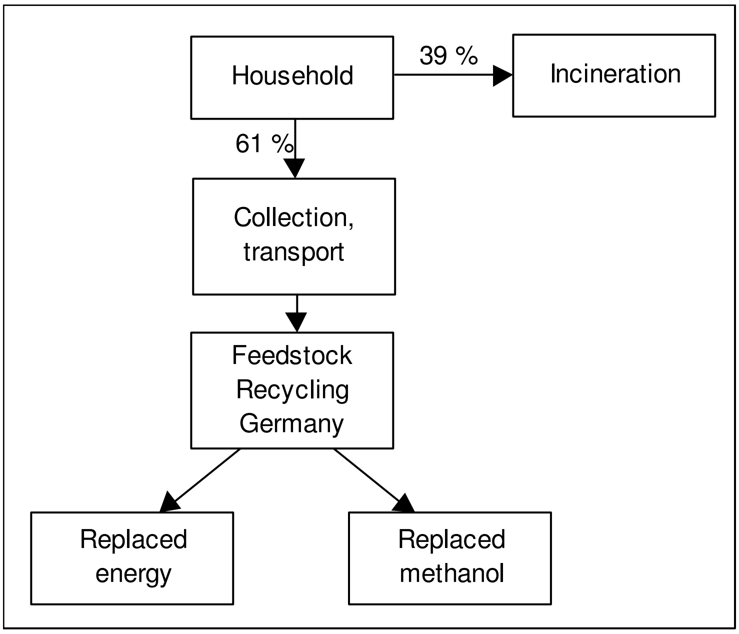

***Figure 4**:’Feedstock 61%’: source sorting with 61% collection rate and feedstock recycling in Germany.*

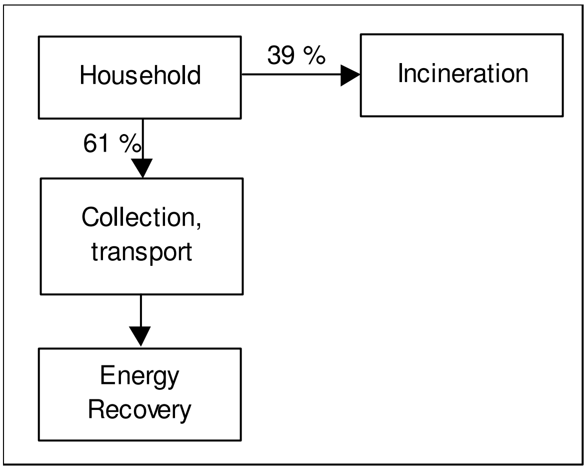

Figure 5: *Energy 61%': source sorting with 61% collection rate and energy recovery in Denmark.*

4 Data and Assumptions

4.1 Environmental data

The data used for mechanical recycling comes from earlier studies [2] and [3]. For feedstock recycling, specific data for SVZ's facility comes from the Fraunhofer Institut, 2000 [1].

For mechanical recycling, it is assumed that the collected plastic is pressed locally and transported to the sorting facility. For feedstock recycling and energy recovery, it is assumed that the collected plastic does not require sorting. For these alternatives the plastic is pressed and transported directly by lorry to Spreetal in Germany and Aalborg in Denmark respectively.

Incineration with energy recovery:
In the analysis is it assumed that the amount of plastic that is not source sorted, is incinerated in a waste incinerator with an energy recovery efficiency of 75% (average for Norwegian facilities). It is further assumed that 75% of this recovered energy replaces oil and 25% replaces electricity.

Mechanical and Feedstock Recycling:
For mechanical recycling it is assumed that the regranulate replaces virgin produced granulate. For feedstock recycling it is assumed that methanol and electricity, that are produced in the process, replaces German produced methanol and electricity.

In the calculations performed, no allowance is made for the extra benefits that can arise from recycling of plastic several times (mechanically, or via feedstock recycling). This recycling can occur several times before the plastic is finally sent to energy recovery [4].

Energy Recovery of source sorted plastic ('energy plastic')
Not all plastic packaging can be mechanically recycled with today's technology. There can be different reasons for this, for example: the plastic packaging is made from laminates and/or that there are different types of plastic in the same product; that the packaging is soiled by food remnants; that there are large costs associated with a greater sorting rate with the use of today's manual sorting technology etc. These factors mean that a larger fraction of the collected plastic is sorted for use as an energy source in industry (energy recovery). Incineration of the sorted plastic is assumed to take place in industrial processes (cement production) that have continual requirements for energy, and a high energy recovery rate (~100%). The plastic is assumed to replace coal [5]. These factors mean that energy recovery gives a significantly greater environmental benefit that incineration with energy recovery in a waste incinerator.

In the final phase of the project it became clear that in 2003 Plastretur will be sending the 'energy plastic' to Aalborg Portland AS in Denmark (cement producer). After contacting Aalborg Portland AS directly [10], the authors found that the correct assumption for energy recovery in this particular facility is that plastic replaces petroleum coke (petcoke). It is likely that this will mean a greater environmental benefit than the replacement of coal, as it is assumed that 'petcoke' is a 'more dirty' energy carrier than coal. This should be analysed in greater detail.

5 Nett Environmental Benefit

The nett environmental benefit is presented for the following environmental impacts:
- Primary energy consumption
- Greenhouse effect
- Acidification
- Eutrophication

Table 2, below, shows examples of which emissions contribute to the different environmental impacts and the potential environmental effects these can give.

Environmental impact category	Example of emission	Potential environmental effects these can lead to:
Global climate change/ greenhouse effect	CO_2 N_2O CH_4 CF_4/C_2F_6	Temperature increase in the lower part of the atmosphere (greenhouse effect and climate change). This is likely to lead to serious consequences for Earth, in the form of changed/more extreme climate, increased desertification, raised water levels due to glaciers melting, etc.
Acidification	SO_2 HCl NO_x	Fish death, death of forests, corrosion damage, damage to buildings, release of heavy metals with effects on animals, vegetation and health.
Eutrophication	Tot N, water Tot P, water	Increased algae growth as a result of the addition of nutrients can lead to a lack of oxygen and local overgrowth effects in both fresh and salt water.

Table 2: *Connection between environmental impact category, emissions and potential environmental effects.*

The environmental benefits for the different waste treatment alternatives assessed are shown in the remaining sections of this chapter, 5.1- 5.5.

5.1 Primary Energy Consumption

Included in ’Energy consumption’ is the consumption of energy that is incorporated in the material, energy that is consumed in order to extract and produce energy carriers, energy for the operation of the different processes involved, as well as energy for transport.

Figure 6 shows the consumption of primary energy in MJ per tonne plastic for the different alternatives.

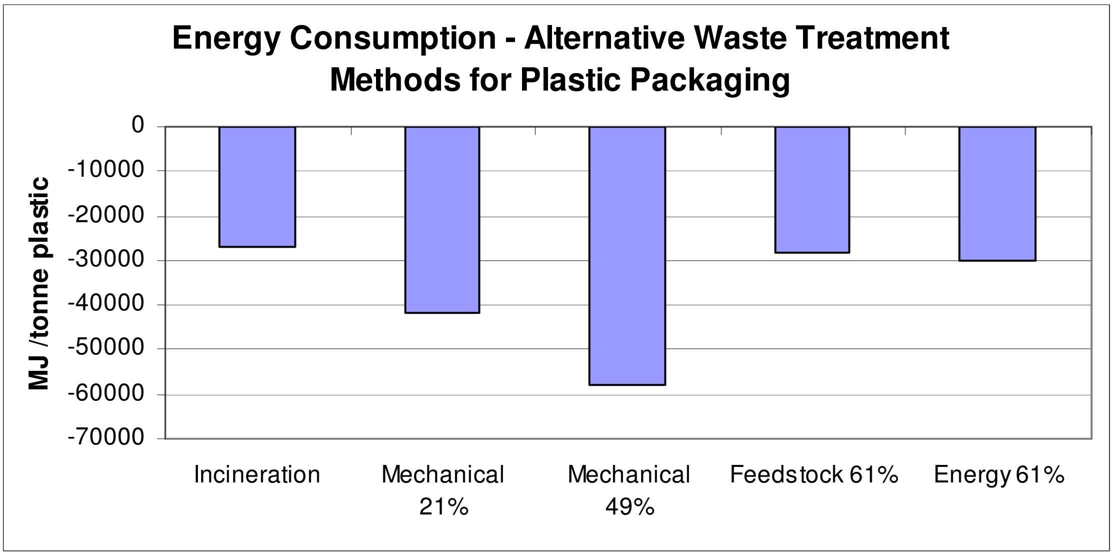

Figure 6: *Primary energy consumption in MJ per tonne plastic for the different plastic packaging waste treatment alternatives.*

All of the waste treatment alternatives presented lead to energy savings. This is shown by the negative energy use in Figure 6.

Mechanical recycling (49%) leads to the largest energy saving of about 60 000 MJ, or 16 500 kWh per tonne plastic recycled. This is equivalent to about 70% of the annual energy use for an average home in Norway [6].

The highest rate of material recycling has the best result as recycling plastic mechanically as a replacement for virgin plastic leads to the greatest saving in energy consumption. This is because production of virgin plastic is a resource intensive process (i.e. '2 kg oil to produce 1 kg plastic').

It can also be seen that mechanical recycling using a collection system (as is in operation in the Hamar and Molde regions, 61% collection rate and 21% collection rate respectively) gives the next best result for energy consumption. Feedstock recycling and energy recovery (61% collection rate), as well as incineration with 75% energy recovery have similar results, with energy savings of around 30 000 MJ per tonne plastic.

5.2 Greenhouse effect

Figure 7 shows the contributions to the greenhouse effect in kg CO_2-equivalents per tonne plastic for the different waste treatment alternatives.

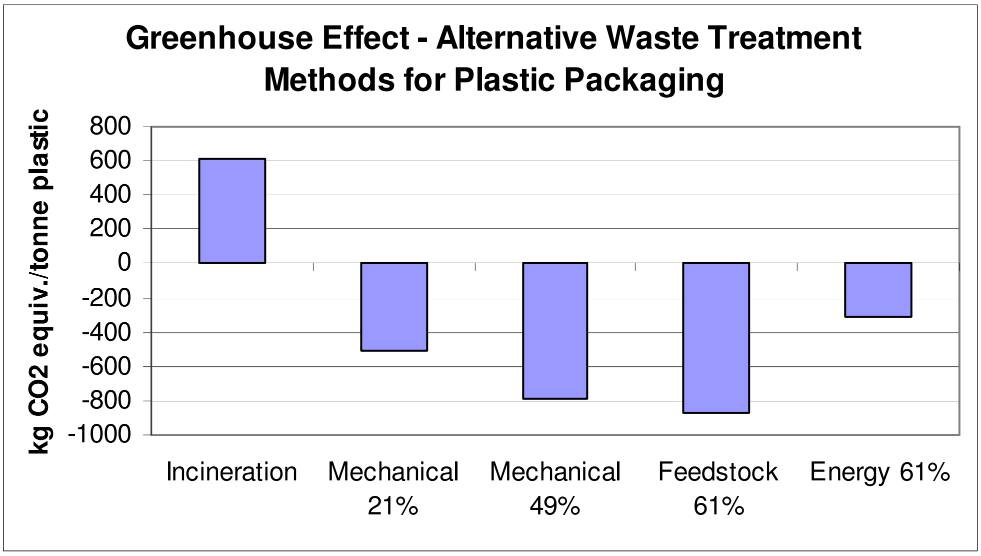

Figure 7: *Contribution to the greenhouse effect potential for the different plastic packaging waste treatment alternatives.*

The figure shows that feedstock recycling and mechanical recycling (49%) are clearly best when considering the greenhouse effect potential for the different waste treatment alternatives. Both of these alternatives give a saving of approximately 800kg CO_2 per tonne plastic packing waste arising in households. This is equivalent to about 80% of the annual CO_2 emissions from private car use for an 'average Norwegian' [7]. Feedstock recycling gives a marginally greater environmental benefit than mechanical recycling (49%), but the difference between these two alternatives is not significant given the level of certainty for the calculations.

Mechanical recycling with a collection system like that in the Hamar and Molde regions today (61% collection rate, 21% recycling rate) is the third best alternative, while energy recovery of source sorted plastic in cement kilns comes fourth. These alternatives give rise to nett savings of CO_2 emissions of approximately 500 kg ('Mechanical 21%') and 300 kg CO_2 ('Energy 61%') per tonne plastic respectively. This is equivalent to approx. 50% and 30% of the annual CO_2 emissions from private car use for an 'average Norwegian' [7].

Incineration in a waste incinerator gives clearly the worst result with a nett emission of greenhouse gasses of approx. 600kg CO_2 per tonne plastic. This is a result of the fact that emissions of CO_2 from incineration of plastic are higher than the saved CO_2 emissions from incineration of oil (based on 75% energy recovery rate).

5.3 Acidification

Figure 8 shows the contributions to acidification potential in g SO_2-equivalents per tonne plastic for the different waste treatment alternatives.

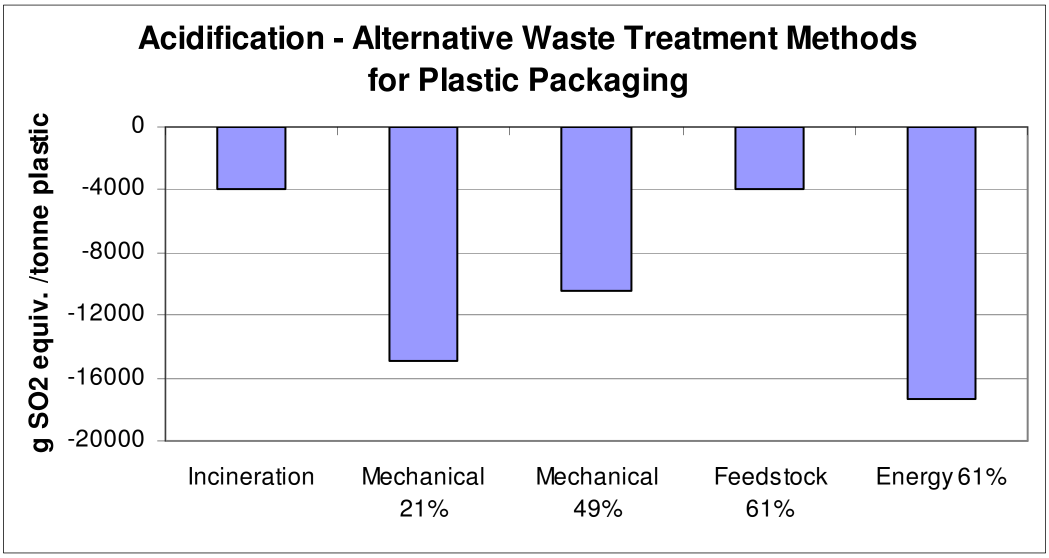

Figure 8: *Contribution to acidification potential for the different plastic packaging waste treatment alternatives.*

Figure 8 shows that industrial energy recovery (Energy 61%) gives rise to the greatest environmental benefit, with a saving of about 17 kg SO_2 per tonne plastic generated in households. Mechanical recycling, with collection and recycling rates like those in the Hamar and Molde regions today (Mechanical 21%) are the next best alternatives with nett savings of SO_2 emissions of about 15 kg per tonne plastic. After that comes 'Mechanical 49%' in third place with saved SO_2 emissions of about 10 kg per tonne plastic.

Feedstock recycling and incineration at a waste incineration facility give the worst results. They have about the same results for acidification, both have a potential saving of about 4kg SO_2 per tonne plastic.

The reasons that industrial energy recovery of source sorted plastic (cement kiln in Denmark) gives the greatest environmental benefit are a high rate of energy recovery (100%) and the replacement of coal. Coal is a relatively 'dirty' energy carrier in relation to sulphur content and thus saved emissions from coal provide a great environmental benefit.

The alternative 'Mechanical 21%' has a higher percentage of source sorted plastic that goes to energy recovery in Denmark than 'Mechanical 49%' (40% and 12% respectively). This means that, for the acidification impact category, energy recovery with high energy efficiency and replacement of coal gives a greater environmental benefit than mechanical recycling.

5.4 Eutrophication

Figure 9 shows the contribution to eutrophication in g O_2 equivalents per tonne plastic for the different waste treatment alternatives.

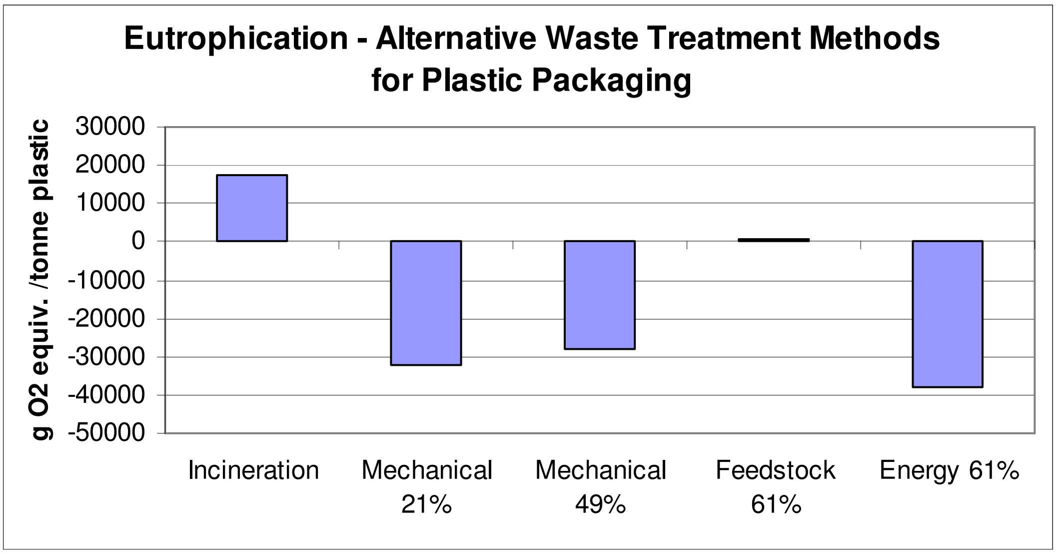

***Figure 9**: Contribution to eutrophication potential for the different plastic packaging waste treatment alternatives.*

The figure shows that industrial energy recovery (Energy 61%) and mechanical recycling (both 21% and 49%) give nett environmental benefits for the eutrophication impact category.

Energy 61% gives rise to the greatest environmental benefits, mechanical recycling with collection and recycling rates like those in the Hamar and Molde regions today (Mechanical 21%) is the next best alternative, but mechanical recycling with a recycling rate of 49% is the third best alternative.

This means that energy recovery with a high energy efficiency that replaces coal also has a greater environmental benefit for the impact category eutrophication, than a high rate of mechanical recycling. The reason for this is the same as for the impact category acidification: extraction and burning of coal gives rise to high NO_x emissions (that are the largest contributor to eutrophication). This means that the saved emissions from this energy carrier give rise to large environmental benefits.

Incineration in a waste incinerator gives clearly the worst result, with an environmental impact of 18000g O_2 equivalents per tonne plastic.

5.5 Summary of Environmental Benefits

The analyses performed show that the tanking between the different alternatives varies depending on which type of environmental impact is assessed, but incineration in a waste incinerator gives the least environmental benefit for all of the environmental impact categories assessed.

In Table 4 the results for the different environmental impact categories are given.

Environmental impact category	Incinera-tion	Mechanical 21%	Mechanical 49%	Feedstock 61%	Energy 61%
Energy consumption	5	2	1	4	3
Greenhouse effect	5	3	2	1	4
Acidification	5	2	3	4	1
Eutrophication	5	2	3	4	1

Table 4: *Results for the different environmental impact categories*

The table above shows that the highest rate of mechanical recycling gives the best result for greenhouse effect, while industrial energy recovery of source sorted plastic gives the best result for acidification and eutrophication.

Energy Consumption
Mechanical recycling of plastic packaging waste clearly leads to the largest environmental benefit, and the higher the recycling rate, the larger the environmental benefit. Feedstock recycling and industrial energy recovery as a replacement for coal gives approximately the same environmental benefit, somewhat better than for incineration in a waste incinerator.

Greenhouse Effect
Feedstock recycling gives the largest environmental benefit, marginally better than the highest rate of mechanical recycling (49%). 'Mechanical 21%' is the third best, while industrial energy recovery as a replacement for coal comes fourth. Incineration is clearly the worst alternative.

Acidification
Industrial energy recovery as a replacement for coal gives the largest environmental benefit, in second place comes 'Mechanical 21%' and 'Mechanical 49%'. The lower the rate of mechanical recycling, at the expense of increased industrial energy recovery, the greater the environmental benefit. This is the opposite of the situation for greenhouse effect potential and energy consumption. This is due to the fact that coal, which has higher NO_x and SO_2 emissions for production and use, is assumed to be replaced.

Feedstock recycling and incineration give approximately the same results, giving the lowest environmental benefit for acidification potential.

Eutrophication
Industrial energy recovery as a replacement for coal gives the greatest environmental benefit, somewhat better than 'Mechanical 21%' and 'Mechanical 49%'. It is also true for eutrophication that the lower the rate of mechanical recycling, at the expense of increased industrial energy recovery, the greater the environmental benefit (as for acidification). The differences are not as great as for acidification, but the assumption that coal is replaced by energy recovery is a very important and sensitive parameter for this impact category also.

Feedstock recycling comes fourth, while incineration is clearly the worst alternative.

6 Conclusions

The ranking between the different alternatives varies according to which environmental impact is assessed. The exception to this is incineration in a waste incinerator, which gives the least environmental benefit for all of the assessed environmental impacts.

Feedstock recycling gives a marginally greater environmental benefit than mechanical recycling when one examines the results for greenhouse effect potential. However, for the other environmental impact categories, feedstock recycling gives clearly worse results than both the high rate (49%) and lower rate (21%) of mechanical recycling.

Industrial energy recovery as a replacement for coal gives the greatest environmental benefit for the impact categories acidification and eutrophication.

It should be emphasised that this study has been carried out using crude/coarse/rough analyses of environmental benefit for different waste treatment methods for plastic. This means that the most important assumptions used in the analyses for the different treatment methods have been revealed. If the results are to be used as an important part of the strategy work to find the most environmentally and economically beneficial methods for recycling plastic, it is recommended that further studies are carried out in order to more thoroughly analyse the systems and test the most sensitive assumptions and parameters. This is particularly relevant for the assumption that industrial energy recovery from plastic in cement production replaces coal, as well as quality control of data and assumptions used for the analysis of feedstock recycling in Germany.

With this background, as well as the EU proposal that feedstock recycling shall not be counted as material recycling, it is recommended that a more comprehensive study is carried out. This can be the basis for important input to both strategic decisions for Plastretur and the EU directive.

7 References

[1]Bez, J., Kremer, M. (Mars 2000): *Verwertung von Kunstoffabfällen aus Sammlungen des Dualen Systems im Verfahren des Dualen Systems im Verfahren des Sekundärrohstoff-Verwertungszentrums Schwarze Pumpe, Ökologische Analyse nach dem LCA-Prinzip*, Fraunhofer Institut, Freising, Germany.

[2] Raadal, H. L , von Krogh, L., Nyland, C. A., Hanssen, O. J. (2001): *Miljø- og samfunnsøkonomisk vurdering av håndtering av plastemballasjeavfall fra husholdninger in Hamar- og Drammensregionen* (Environmental and socio-economic assessment of the treatment of plastic packaging waste from households in the Hamar and Drammen regions), Stiftelsen Østfoldforskning, OR.24.01

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

[4] Nyland, C. A.. L., Raadal, H. L ,Hanssen, O. J., and Modahl, I. S.: ”How LCA is Used for Assessment of Waste Management Systems, Including a Model Allowing for Recycling of Material Several Times”, article sent in for review, February 2003.

[5] Schefte, Geir: e-mail, 12.11.02.

[6] Bøeng, A. C., Nesbakken, R., 1999: Energyforbruk til stasjonære and mobile formål per husholdning 1993, 1994, 1995. Gjennomsnittstall basert på forbruksundersøkelse (Energy consumption for stationary and mobile uses per household 1993, 1994, 1995. Average data based on a consumer questionnaire). Statistics Norway, report 99/22.

[7] SSB (Statistics Norway), 2002: Årlig statistikk veitrafikk, personbiler (Annual statistics, road transport, private cars). Statistikk befolkning in Norge (Statistics, population in Norway).

[8] Information from the database in LCA-simulation program Simapro.

[9] Magnussen, K., Rønning, A., Møller, H. 1998: Vekting in LCA (Weighting in LCA), Østfold Research Foundation, OR 11.98.

[10] Mogensen, O. (Aalborg Portland A/S): e-mail, 27.01.03 .