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Costs and Benefits of Recycling Liquid Board Containers

ABSTRACT. Recycling of packaging material has become more or less mandatory in many European countries, including Norway. Through so-called voluntary agreements quantitative targets are set for the proportion of total waste to be recycled. At the same time the strategic objective for Norwegian waste policy is that there should be a socio-economic balance between different waste treatment options. On the basis of a cost-benefit analysis it is questioned whether the Norwegian recycling policy for liquid board containers really is cost-effective. The calculations show that the net social costs of the recycling system in 1999 amounted to €3.5 million. The high cost is due to the fact that these containers constitute a small fraction of total waste from the household and that it is costly to separate it from other waste. The environmental costs from landfilling or incineration are small compared to the costs of recycling. The best alternative, according to our analysis, is to incinerate the containers with energy recovery.

For the last decade there has been a growing concern among environmental authorities regarding waste handling, and waste policies have become more explicit. One waste handling policy that has become more or less mandatory is recycling, and it is often regarded as the second most desired option in waste policies, where the most desired option is reduced waste generation. The underlying goals when promoting recycling is to save natural resources and to reduce the amounts of waste being either incinerated or dumped at waste disposal sites. The first goal results from an assumption that virgin material is becoming scarcer, but there are legitimate arguments to doubt this assumption, see for instance Tilton (1999). The last goal follows from the assumption that incineration and landfilling are more environmentally harmful than recycling.

In many European countries recycling efforts have particularly focused on packaging material. Recycling of packaging material is generally determined by mandatory regulations, with explicit targets for recycled shares. Since packaging material does not constitute a major part of total waste, and in many cases consists of rather harmless substances, the strong policies towards these materials must be based

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on something other than the actual environmental harm they cause. One possible explanation is that packaging material, rightly or not, has been regarded as a picture of our over-consumption. Another explanation is that packaging material is a rather obvious waste fraction in the household – a fraction that we deal with almost every day, and that is easily separated from other types of waste.

Norway is one of the countries with explicit targets for recycled shares of packaging material. At the same time the overall goal for Norwegian waste policy is, as stated in White Paper No. 8 (1999–2000):

> "Waste problems shall be solved in a way that minimizes damage and nuisance to people and the environment *and at the same time minimizes the resources used in waste management*" (our italics).

We do not, in this paper, question or discuss the overarching waste policy objectives in Norway. Our objective is less ambitious. The point of departure is that when waste, in our case one tonne of liquid board containers, has been "generated" in the individual households, the problem at hand is the disposal of that waste. According to the above stated policy goal, the disposal should be carried out by using that option, or combination of options, that demands the least of society's resources.

The overall goal in this analysis is to determine the most cost-efficient way to treat one tonne of liquid board container waste. Different treatments to be analysed are: recycling of the paper content, incineration with or without energy recovery, and landfill. Liquid board containers that are being analysed include all disposable containers for non-fizzy, non-alcoholic beverages (for instance, milk and juice), and containers for sauce, puddings, and liquid detergents. The data used apply to Norway.

We also compare the cost-benefit analysis with a purely environmental analysis, closely resembling a life cycle assessment (LCA). There are many LCAs done with the purpose of determining the most environmentally friendly way to treat waste, and it appears that the outcome of these has had important influence on the mandatory targets for recycling, see for instance Finnveden and Ekvall (1998) and Jensen (1997).

The issue of recycling and cost-efficient treatment of waste has been discussed and analysed in a number of papers, see for instance Brisson (1996), Bruvoll (1998), Goddard (1995), Leach, Bauen, and Lucas

(1997), and Radetzki (2000). In Norway there has been a debate about the benefits of recycling of packaging materials. The proponents of recycling often use LCA in order to uncover the environmental benefits of recycling, and then argue that all projects or measures that are environmentally beneficial should be carried out regardless of the cost to society. The critics, on the other hand, argue that, in many cases, the costs of achieving this environmental benefit are much higher than the value of this benefit, i.e., that it is not cost efficient to use resources in order to recycle every waste fraction from the households.

The paper is set out as follows: We first provide a comprehensive description of cost-benefit analysis, and also discuss some concepts in a cost-benefit analysis that have sparked debate, particularly with proponents of LCA. These controversial concepts include valuing the environment, valuing time use in households, marginal energy source, and the fact that a cost-benefit analysis usually is strictly domestic, thereby ignoring environmental harm occurring in other countries. The third section describes how liquid board containers are treated in Norway today. In the fourth section the results from the CBA are presented, first in the form of a main alternative, but then also when changing the assumptions. The fifth, and final, section discusses the results and the conclusion to be drawn from the results.

COST-BENEFIT ANALYSIS: THE METHOD

Introduction

Cost-benefit analysis (CBA) is a straightforward economic evaluation method. It has its theoretical foundation in welfare economics and determines the net benefits (the contribution to welfare) of a project/policy by comparing its social costs and benefits. The main criterion for evaluation is economic efficiency, i.e., that a given policy objective is achieved at the least costs. When all impacts of a proposed policy or project have been established and measured in monetary units through the use of social shadow prices, those projects/polices with positive net benefits should be carried out. Alternatively, under budget restrictions, projects should be prioritized in descending order by the value of the benefit-cost ratio.

Increasingly, environmental policy changes are subjected to CBA in Western countries. For example the US EPA has recently developed a thorough and comprehensive set of guidelines to policy-makers for economic analysis of environmental policies (US EPA, 2000). Likewise, in Norwegian policy-making there is an increasing tendency to use CBA as part of the basis for decisions, spurred by recommendations from the public Committee Reports on CBA (NOU, 1997, 1998).

Waste management is, like many other environmental policy issues, full of controversy between economists, engineers, and natural scientists as well as other stakeholders in Norway and internationally. The principles and procedures of CBA are relatively well accepted among economists, but much less understood, let alone accepted, by other disciplines. In order to clarify some of this interdisciplinary controversy about the use of CBA in waste policies and to make the case for CBA principles, we take a step back in this section and explain four important issues in the use of CBA which are particularly relevant to our case:

- valuing the environment
- valuing time use
- marginal environmental costs of energy production
- counting domestic costs and benefits only.

Valuing the Environment

A recurring theme within environmental economics and across different disciplines is the debate about valuing the environment. This theme, with all its important philosophical ramifications, is not the topic for this paper. Instead, we choose to follow the emerging CBA practice in Western countries.

Policies have environmental effects, as well as other effects, that cannot readily be measured and compared to effects which are directly valued in markets. Economists try to value non-market benefits, such as environmental benefits and costs, in order to be able to compare all effects of a project.

Even if the valuation of benefit and cost streams of certain policies is often fraught with methodological and practical difficulties, it is usually not a good alternative to leave out an attempted estimation of these effects. All political decisions involve prioritizing, and the better and more comprehensive the available information is for the decision-maker, the better the decision is likely to be. A decision made without a measure of the value of environmental effects, will moreover implicitly assign a value to these effects. Therefore, most CBA guidelines say that environmental effects should be included explicitly in the CBA, and as far as possible measured in monetary terms (e.g., NOU, 1997; US EPA, 2000).

The major environmental effects of waste treatment, from generation to the point where the waste is recycled, incinerated, or landfilled, are emissions and discharges to air and water from the different waste treatment options and emissions to air from transport. The environmental effects are both health and ecosystem effects. We value the environmental damages (or saved damages from recycling) mainly using relevant international or Norwegian studies; see Ibenholt and Lindhjem (2002) for a presentation of the values used.

Valuing Time Use

The principle of valuing time use. Valuation of people's time originated early last century in studies of public transport infrastructure projects that reduce traffic congestion and reduce travel time. For many transport projects saved time is the major benefit component in CBAs, and often of pivotal importance to the investment decision.

Currently, most valuations of time use have been carried out in the transport sector, but there is broad agreement that the value of the (change of) time use as a result of a public policy change or project, should be taken into account in all sectors, including the waste management sector (NOU, 1997).

The main principle of time valuation is the same as for valuation of any other good, i.e., the value of that good in its alternative use, in other words the value of the time that is displaced or freed when a public policy/project requires a change in people's time use.

A classical way of estimating the value of time displaced is firstly to determine whether the alternative use is leisure time or work time. If work time is displaced, the correct alternative value is the value of the marginal productivity of that work, i.e., the (hourly) gross wage cost. If a person's leisure time is displaced, the question is how people value this time. According to welfare theory, people supply their labour to the point where the gain from working another hour is equal to the value of that time as leisure. This presupposes that people can supply labour and be employed in a flexible market. In such a market the value of an hour of leisure time is thus equal to the net hourly wage rate (the wage rate minus marginal tax). This valuation procedure may not always be clear-cut, for reasons connected both to strong market assumptions and the difficulty of determining the nature of the time displaced.

The classical method of time valuation has been challenged in recent years by revealed and stated preference methods that more directly try to evaluate the value of time.

The value of time spent by households sorting and cleaning liquid board containers. In CBAs where different waste treatment options are compared, the time used by households to sort, clean, fold, and deliver waste in different bins, etc., is, to economists, a potentially important cost component for the recycling alternative (see, e.g., Bruvoll, 1998). There has been a considerable controversy concerning this point in the interdisciplinary debate about waste management options in Norway. The main point of disagreement is whether the time used should at all be included as a cost in the CBA since, some argue, waste management is voluntary and for many people a meaningful and valued activity. To economists this would suggest that people are not willing to pay anything for the sorting, etc., to be taken over by, e.g., the municipality, or that some even are willing to pay a positive amount to be allowed to continue doing the work.

To find out more about people's attitudes and motives for doing recycling work in the household, and eventually to find a more accurate basis for valuing the time use (positively or negatively), Bruvoll, Halvorsen, and Nyborg (2000) carried out a large survey in the Norwegian population. They found that 93 per cent of the people surveyed do some kind of recycling efforts at home, and that the total amount of time spent by the participants in the survey is 28 minutes per week, or 41 hours per year. This figure may be slightly on the high side mainly because people tend to overreport their efforts in questionnaire-based surveys (see, e.g., Marini & Shelton, 1993). Besides, laboratory experiments show slightly lower figures (Konsumentverket, 1997). The survey did not include enough information to enable a differentiation between the amounts of time spent sorting different fractions. The average estimate for all fractions of 28 minutes underestimates the rather more time-consuming recycling effort required for liquid board containers (sorting, cleaning, folding) compared to, for example, newspapers.

As to the valuation of this reported time use the study asked several questions related to both the motives for doing the work and willingness to pay (WTP) to be spared the work. As a general tendency, the authors found that people are willing to pay something to be spared the job, and conclude that there are rather compelling reasons to believe that most people regard the recycling efforts as a strain and therefore that the time spent should be included as a cost in CBAs.

The average WTP to be spared the work is NOK 176, equalling €22.6, per household. This amounts to €103 per tonne of sorted waste or €88 when cleaning costs (from water use) are subtracted. This gives a rather low hourly rate for the work of €0.45. Interestingly, the study found that people who spend less than five hours per year on sorting, etc., have an hourly rate as high as €22. This might suggest that the social costs of domestic recycling efforts may increase when recycling schemes are extended and increased, demanding a larger share of the time that is dearly valued.

Marginal Environmental Costs of Energy Production

A CBA generally takes the initial state of the national economy as given, and looks at the net addition to national wealth from an investment or a project which is too small to change prices and market conditions. The project causes marginal changes of resource use and benefits, which should be valued at given socially adjusted "spot" prices for the different project periods.

For CBAs with a long timespan shadow prices change. One important shadow price is the social cost of energy production. For Norway it is commonly assumed that the current marginal source of energy is electricity generated at coal-fired plants in Denmark. This means that energy generated at waste incineration substitutes for coal, which is assumed to be an environmentally quite harmful energy source.

Over time the marginal source of electricity in Norway is supposed to change and in 10–15 years it is likely to be gas-fired plants.

Counting Domestic Costs and Benefits Only

In a CBA the correct social shadow price of an imported good/resource is the price at the country border (net of fiscal, Norwegian taxes). This principle is based on the idea of sovereignty of nations, and that each nation is free to decide how to value its own environment.

Basically this means that any environmental costs in the exporting country are supposed to be included in the export price. If an environmental tax is levied on the production of a good for example, then this tax is reflected in the price paid at the border. If the production of a good is subject to environmental regulations, that good is more expensive to produce than it otherwise would have been, and therefore, again, more expensive to import. If there are no environmental taxes levied on the good/resource, we assume that the exporting country values (additional) local environmental damages from the manufacturing of the good as equal to zero. In this case we can disagree with the country's priorities, but can as a matter of principle not use a different calculation price. Thus, local environmental costs in countries from which we import should not be included in a Norwegian CBA.

Regional environmental damage is an intermediate case. If the production of a good entails emissions which damage the environment in several countries (e.g., sulphur to air or chemicals to rivers) and the total effect is not taken into account through environmental taxes in the exporting country, then the value of (marginal) environmental damage in the importing country must be added to the border price in a CBA. Regional environmental problems are complex, and the most serious of them are subject to international treaties whose implicit valuation is reflected in product prices. One can either use this implicit valuation, or make independent marginal damage estimates which are added to the core price (i.e., net of the treaty-effect).

Emissions that cause *global* environmental damages is the other extreme from local damages. Greenhouse gases (GHGs) cause (for all practical purposes) the same environmental damage wherever they are emitted. If the emissions increase in Finland and Denmark because of increased Norwegian electricity demand, the environmental consequences for Norway will be exactly the same as if the GHGs were emitted there. It is therefore valid to argue that the emissions should be valued as if they were Norwegian. We can value the emissions of GHGs *either* as equal to the environmental tax, *or* make an independent estimate based on climate damage modelling or other methods (if we deem the tax to be inaccurate).

In our current CBA the problem of choosing an accurate shadow price for imported goods and resources is relevant both in connection with (saved) import of electricity from other Nordic countries (see above) and (saved) import of timber for Norwegian paper production.

Paper is produced either by using virgin materials – domestically produced or imported – or recycled materials from, e.g., liquid board containers. Extraction of timber can be both a local and a global environmental problem, or not a problem at all, depending on the forest source. Forests are a renewable resource and may, if managed sustainably over time, yield timber products for the world markets for all eternity. In some areas of the world, and especially in the tropics, massive deforestation is taken place, while in other areas, like Norway, the opposite holds.

If deforestation was regarded only as a local issue (problem or not), the arguments above say that the price at the Norwegian border should be used as the shadow price regardless of whether timber extraction has been subjected to environmental regulations/taxes or not. We may disagree strongly with foreign forestry policy but if it is a local issue only, the price at the Norwegian border should be used in a CBA.

Many regard deforestation as a global problem, particularly in relation to shrinking biodiversity and the increasing release of GHGs. In principle, the price of timber at the border should be adjusted for these global environmental damages in the same way as for emissions of GHGs from power production. However, as opposed to global warming, there is hardly any knowledge, let alone value estimates, of the global (marginal) environmental damage of biodiversity loss from timber production.

Raw material for paper production comes predominantly from temperate forest plantations, whose volume is expanding. Therefore, in this particular case the problem of deforestation is of very small practical significance, as appears from the externality figures in Table III.

THE HANDLING OF LIQUID BOARD CONTAINERS IN NORWAY

Through so-called voluntary agreements the producers and users of packaging in Norway have committed themselves to provide for collection and recycling of certain amounts of generated waste from packaging.

Regulations

General goals and principles of Norwegian waste policy. The overall strategic goal for Norwegian waste policy is as stated above, i.e., to handle the waste problem in a cost-efficient manner for the people as well as for the environment. The operational goals are that the growth in waste generated shall, over time, be considerably lower than the economic growth, and that the amount of waste landfilled or incinerated without energy recovery shall be reduced in line with what is economically and environmentally sensible.

Policies for the handling of liquid board containers. The EC Directive concerning packaging waste has been in force in Norway since June 1996 through the EEA Treaty. The main requirements in the Directive are that in 2001, a minimum of 50 per cent and a maximum of 65 per cent of the total amount of packaging waste (measured in weight) should be recovered, and that a minimum of 25 per cent and a maximum of 45 per cent of the waste should be recycled either as materials or energy.

In order to fulfil this Directive a set of voluntary agreements between major actors in the private packaging sector and the Ministry of Environment were signed. The agreements represent a way to implement "producer responsibility," that is to make producers and users of packaging (the packaging chain) responsible for their product from "cradle to grave." In short, the agreements state that the packaging waste chains are responsible for collection, marketing, and selling the collected materials for recycling. These tasks are in the agreements allocated to so-called material companies, which the packaging chains were obligated to establish.

For liquid board containers in particular the agreement requires that at least 60 per cent of all waste in Norway shall be collected and materially recovered. Energy recovery was not an option in the original agreement signed in 1996. The agreements were renegotiated in 2003, but energy recovery is still not included as a valid option.

Recycling of Liquid Board Containers

In 1999 about 18,500 tonnes of liquid board container waste were generated in Norway; 85 per cent by households and 15 per cent by industry. This amounts to about 5 per cent of packaging waste and about 1.3 per cent of all domestic waste. Most of these containers are used for milk and juice and made out of a cardboard material coated with plastic and in some cases also aluminium.

The material company "Norsk Returkartong" (NR) administers recycling of liquid board containers. The manufacturers and packers/fillers of these containers established NR in 1994, as a part of the agreement described above. The company's main task is to administer the collection and recycling of the containers. The activity at NR is financed by a consideration paid by all members of the "packaging chain" for liquid board containers, equalling €0.0036 (or NOK 0.028) per container in 1999. With 750 millions of containers used per year this gives an income of €2.7 million. NR reports that for 1999 43 per cent of liquid board containers were collected and 39 per cent of the material recovered.

Currently 96 per cent of the Norwegian population is offered the opportunity to hand in liquid board containers in their own municipality. The collection systems vary widely between municipalities. Some municipalities collect waste in sorted fractions, i.e., the households themselves sort the waste into two or more fractions. Overall, most of the liquid board containers are collected from households in a bin containing all paper and cardboard, so-called mixed paper collection.

If liquid board containers are collected in a waste bin together with other paper and cardboard or in an unsorted fraction altogether, the waste is transported to a central facility and sorted there. Another, and less common system in Norway, is for people to deliver the liquid board containers to a number of geographically distributed collection containers or to the sorting facility itself, hereafter called a delivery system.

When the containers have been collected they are sorted, squeezed into compact units, and sold by the municipality or through private wholesale dealers. NR buys all the collected and pressed containers at a fixed price equalling €128 per tonne.

The containers are then sold either to recycling facilities abroad or to the Norwegian recycler Hurum Factories, located in the southern part of Norway. The factor is only willing to pay a price that corresponds to the world market price for fibres. Usually this price is lower than the €128 per tonne that NR pays for the containers, meaning that NR has to subsidize every tonne of liquid board containers collected.

The subsidy varies between €0 and €89, depending on the world market price.

The fibres in the containers are of high quality and are in demand as input in the production of new paper products such as envelopes, paper bags, liners, etc. Hurum Factories uses the fibres in the production of coloured cardboard, paper for envelopes, and various office accessories.

Other Waste Treatment Options

The alternative to recycling of liquid board containers is incineration, with or without energy recovery, and landfill. These options all have some shortcomings in the form of environmental effects, but on the other hand they offer relatively cheap treatment and do not requie the waste to be sorted for treatment.

Incineration. Incineration of waste is currently carried out at plants both with and without energy recovery, but the latter alternative is becoming less used. Today, all incineration plants in Norway burning mixed waste have some energy recovery, and in 1999 the recovery rate ranged from 10 to 100 per cent, with an average of 72.5 per cent. The technology used for incineration differs, as do the emissions. There still are plants with only basic cleaning equipment and rather high emission factors, while the latest technologies have low emissions factors for almost all substances. Table I gives an overview of emissions from Norwegian wate incineration plants in 1999, and from incineration of liquid board containers.

Landfill. Landfilling is still the most common alternative for waste in Norway, and in 1999 slightly less than 50 per cent of municipal waste was disposed of this way. During the 1990s there has been a movement away from small and unsafe disposal sites towards larger and safer sites. By safer we mean sites where there is only minor leakage of substances to water and soil, i.e., a lined landfill, and where the gas generated is collected. There are no reliable statistics for leakage and emissions from waste dispoal sites, but based on SFT (1996) and Tellus Institute (1991) we have calculated that the landfilling of 1 tonne of liquid board containers results in environmental damages as reported in Table II.

TABLE I
Pollutant Emissions from Incineration of Mixed Waste and Liquid Board Containers, per Tonne of Waste, 1999 and Average 1996–1999

		Mixed waste[1]			Liquid board containers	
	Unit	Average	Cleanest	Dirtiest	Average[2]	Cleanest
Cd	Kg	0.00011	0.00000007	0.00068	0.030	0.00015
CO	Tonnes	0.00045	0.000014	0.0028	0.00056	0.00056
Dioxin	g	0.000007	0.00000003	0.000019	0.0000099	0.00000015
HCl	Kg	0.154	0.0013	0.78	0.015	0.0065
HF	Kg	0.0053	0.00015	0.042	–	–
Hg	Kg	0.000058	0.00000029	0.00017	0.000014	0.0000020
Particular matter	Tonnes	0.000058	0.0000013	0.00017	0.000064	0.0000019
Ni+As	Kg	0.0017	–	0.0072	0.0016	0.0000082
Pb+Cr+Cu+Mn	Kg	0.0020	0.000024	0.011	0.0022	0.000012
SO_2	Tonnes	0.00031	0.000016	0.0013	0.00052	0.000084
NO_x	Tonnes	0.0015	0.00095	0.0020	0.0022	0.00061

[1] Emissions in 1999.
[2] Average emissions 1996–1999.
Source: Norwegian Pollution Control Authority, ECON (2000).

THE COST-BENEFIT ANALYSIS: DATA AND RESULTS

Data

In order to make a cost-benefit analysis of the Norwegian handling of liquid board containers possible, data were collected on the following activities.

Sorting of waste in households. Using data from Bruvoll et al. (2000) we estimated use of time and resources in the households in order to clean and sort liquid board containers. Since the data in Bruvoll et al. do not distinguish between different waste fractions, we adjusted the figures to fit liquid board containers. We use the average willingness to pay calculated in Bruvoll et al. (2000). But, as mentioned above, this might lead to an underestimation of the real WTP since the marginal WTP probably is higher than the average.

Collection activities at the municipality level. Data about the collection system and costs were gathered from 165 municipalities in Norway through a questionnaire. Based on the data collected we

TABLE II
Pollutant Emissions per Tonne of Landfilled Liquid Board Containers

Pollutant	Unit	Unlined landfill[1]	Lined landfill[2]
Methane	kg	213.1	106.6
CO_2	kg	95.1	142.6
Particulate matter	g	0	3
SO_2	g	0	19
NO_x	kg	0	0.0009
VOC	kg	0	0.000002
Arsenic, As	g	0.00889	0.000087
Barium, Ba	g	0.04345	0.0039
Cadmium, Cd	g	0.00251	0.000012
Chromium, Cr	g	0.05078	0.000019
Copper, Cu	g	1.29724	0.00485
Lead, Pb	g	0.03990	0.000030
Manganese, Mn	g	0.38556	0.0340
Mercury, Hg	g	0.00005	
Nickel, Ni	g	0.00685	0.00060
Selenium, Se	g	0.00011	0.000019
Vanadium, Vn	g	0.00201	0.00018
Zinc, Zn	g	0.56707	0.0045
Acetone	g	0.52	0.04
2-Butane	g	0.95	0.084
p-Cresol	g	0.352	0.03
Other	g	0.2703	0.0239
Nutrients to water			
COD	kg	1.1	0
Nitrogen	kg	0.015	0
Phosphorus	kg	0.00004	0

[1] No gas collection. 25% gas collection will give 25% lower emissions of methane and CO_2, some emissions of particulate matter, SO_2, NO_x, and VOC, and all other emissions equal to no gas collection.
[2] 50% gas collection.
Source: Norwegian Pollution Control Authority, ECON (2000).

calculated weighted averages for each type of collection service for liquid board containers: in the ordinary waste stream, collected at the households either mixed with other waste paper or separately (i.e., curb side collection), and the containers being brought to a central collection spot. The true social costs are the marginal collection costs, but since liquid board containers constitute a rather small fraction of both sorted and unsorted waste, and there are no known bottlenecks in the system, average costs are an acceptable approximation to marginal costs.

Central sorting and treatment. This item includes use of resources in the central sorting of liquid board containers. Based on sorting costs for waste paper with and without these containers we have calculated the marginal sorting costs for liquid board containers. Many sorting facilities differentiate the price according to the composition of the waste paper, with the price depending on the number of paper qualities; the less the number of qualities the lower the price. Waste paper that includes liquid board containers is commonly charged a higher sorting price than waste paper without these containers. Based on the price differences and the amount of containers in total waste, a marginal sorting price for liquid board containers has been estimated.

Traditional treatment. This post includes operating costs and environmental costs for traditional treatment, that is landfill and incineration. The operation costs were gathered in the questionnaire together with the collection costs, whereas figures from ECON (2000) were used for environmental costs.

For the landfill option the environmental costs are calculated under the assumption that 25 per cent of the gas generated is collected, and that the landfill is not lined. Since this represents an old landfill, and does not reflect the true average externalities from Norwegian landfills, the environmental costs are overestimated. In an alternative calculation we have used the figures from a new, and lined, landfill, see below. The true environmental cost lies somewhere in between these figures, but probably closer to the lowest value since old landfills are gradually phased out.

The externalities from incineration are based on the average pollution during 1995–1999. The emissions to air were particularly high during 1996 and 1997, and have decreased considerably since then – therefore the externalities are probably over-estimated.

The recycling system. The operating costs for the recycling system include resources used at NR for administration, information, and the like. These costs also include the subsidy NR gives to the municipalities, as described above. We have used an average market price of €64, giving an indirect subsidy per tonne of liquid board containers that comes up to exactly the same amount. The recycling costs also include transport from the municipalities to Hurum, which NR pays for. NR states that the average transport cost is €35 per tonne.[1]

Production at Hurum. All collected containers are assumed delivered at the Hurum paper mill. In 1999 slightly more than 30 per cent was actually delivered at Hurum, while the rest was exported. We also calculate the external cost at Hurum when using liquid board containers to produce new paper. The external costs are from a study of external costs in using recycled cardboard in paper production (Ibenholt, 1999), so they are not directly equal to the true marginal costs at Hurum. Since Hurum also uses virgin pulp, and other waste paper qualities, it has not been possible to distinguish the actual emissions for the use of liquid board containers. The resulting error from using the figures from Ibenholt (1999) is probably small.

Using virgin pulp. All virgin pulp is assumed to be produced using Norwegian timber, whereas the actual figure is that approximately 65 per cent of the pulp comes from domestic timber and the rest is being imported, mainly from Sweden and the Baltic States.[2] We have assumed that one tonne of liquid board containers equals 0.85 tonnes of pulp.

The price of one tonne of pulp is calculated to be equal to €76. The calculation is based on the fact that liquid board containers compete on price with pulp, and that the average price for one tonne of liquid board containers is €64.

In addition to the market price we have chosen to calculate a shadow price for sustainable forestry, i.e., an externality cost. There is a debate in Norway whether or not the forestry is sustainable. The Forest Owner Association and several forest researchers assert that environmental concerns are being properly handled in the forestry and that the market price includes all externalities. Different environmental organizations, researchers, and producers using Norwegian timber call this in question, and point especially to the low share of protected forest area. The actual protected area of Norwegian forest is less than one per cent. The externality costs we have chosen to include rest on the assumption that the protected area ought to be expanded, and that such an expansion would increase the cost of producing Norwegian timber. The calculation of the cost is based on a protection of 3.6 per cent of total forest area, equalling the protected area in Sweden, a country which is often used for comparisons regarding environmental matters. The size of the externality, or rather a shadow price for forest biodiversity, is calculated as the difference between actual protection and the preferred (or desired) protection. We have assumed constant marginal costs for protection, i.e., a linear cost function. This is a simplication, which most likely will lead to an underestimation of the shadow price, since marginal costs probably increase as larger areas become protected. But due to lack of data in order to estimate the true marginal costs, we have to use this simplification.

Energy production. One tonne of liquid board containers being incinerated with so-called full energy recovery, which is equal to a recovery rate of 72.5 per cent, generates 3.3 MWh of electricity.

The production price for Danish coalfired plants is assumed to be €0.015/kWh, exclusive of the Danish CO_2 tax. One MWh of coal generated electricity is assumed to emit 0.8 tonnes of CO_2.

Results

Under the presumptions mentioned above the results of the cost-benefit analysis is presented in Table III. As can be seen the most cost-effective option seems to be incineration with energy recovery. Regardless of how the containers are collected, material recycling is far more costly than traditional waste handling. The largest cost for the recycling system occurs at NR, the material company, where more than €256 pr tonne of containers are used for administration of the system, inclusive advertising and a million-NOK lottery.

In 1999 7,200 tonnes of liquid board containers were recycled, and the net cost of this activity, using the costs in Table III, are estimated to be almost €3.5 million. In our questionnaire 63 per cent of the collected liquid board containers were mixed with other waste paper, 24 per cent were collected apart from other waste paper, and the remaining 13 per cent were collected in delivery systems. For unsorted waste 42 per cent were sent to landfills and 52 per cent to incineration with energy recovery. The total cost of today's recycling system is calculated on the basis of these rates. The recycling costs amount to €6.0 million, and the costs avoided (i.e., avoidance of landfilling, incineration, and using virgin pulp) amount to €2.5 million, giving a net cost of nearly €3.5 million per year.

TABLE III
Results from the Cost-Benefit Analysis. € per Tonne Liquid Board Container Collected. 1999

	Unsorted waste			Sorted at source		
	Landfill	Incineration	Energy recovery	Collection system – Mixed	Collection system – Separate	Delivery system
Costs for the households				*188*	*188*	*232*
Use of time				111	111	133
Use of resources				77	77	99
Costs for the municipal refuse service	*92*	*92*	*92*	*272*	*67*	*85*
Collection	92	92	92	113	113	173
Central sorting				287	81	40
Payment from NR				–128	–128	–128
Costs for final treatment	*212*	*167*	*134*			
Operation costs	73	81	107			
External costs	139	86	27			
Costs at NR				*374*	*374*	*374*
Transport to Hurum				35	35	35
Administration costs, incl. subsidy				339	339	339
Costs at Hurum				*69*	*69*	*69*
Input costs[1]				64	64	64
Environmental costs				5	5	5
Sum all costs	*304*	*259*	*226*	*903*	*698*	*760*
Alternative production			*96*	*98*	*98*	*98*
Externalities, timber				5	5	5
Resource costs[2]			51	64	64	64
Externalities, production			45	29	29	29
Net social cost	*304*	*259*	*130*	*805*	*600*	*662*

[1] This is the price Hurum, on average, is willing to pay for 1 tonne of liquid board containers. The costs of producing paper products based on one tonne of liquid board containers are supposed to be equal to the costs using any other raw material, and therefore we have chosen to ignore that cost.
[2] This is, respectively, the cost for buying 3.3 MWh electrical power from Denmark, and the cost of buying virgin timber/pulp incl. transportation costs.

Alternative Calculations

We also made some alternative calculations of the costs in which some of the assumptions were changed. The results of these calculations are presented in Table IV.

The alternative *high environmental costs* uses the highest cost estimates in ECON (2000). For incineration, the main difference concerns the valuation of particulate matter, chromium, and dioxin, and for landfilling the valuation of methane, chromium, and lead, and the discount rate used. In the main alternative a discount rate of 3.5 per cent is used, whereas in this alternative a discount rate of 0 per cent is used, meaning that no discounting is undertaken of future environmental effects. For the use of virgin pulp a shadow price corresponding to protection of 15 per cent of total forest area has been used, equalling €60 per tonne of liquid board containers replacing virgin pulp.

The *new technology* alternative assumes that incineration is done at a plant with the best available technology, that the waste disposal site is lined and collects 50 per cent of the gas, that there is no price difference between sorting waste paper with and without liquid board containers, and that the marginal energy source is gas power instead of coal. It is reasonable to assume that gas power will be the marginal energy source within a timespan of 5–10 years. With present technology, this energy source is assumed to emit 0.34 tonnes of CO_2 per MWh generated, 0.65 kg of NO_x, and 0,3 kg VOC (ECON, 2001).

TABLE IV
Alternative Calculations of Net Social Costs of Waste Handling of Liquid Board Containers. € per Tonne. 1999

	Landfill	Incineration	Energy recovery	Mixed collection	Separate collection	Delivery system
High environmental costs	454	279	185	756	881	613
New technology	199	259	131	520	494	586
High prices virgin pulp	304	259	189	741	536	598
No time costs in households	304	259	189	617	411	452
Best case for recycling	454	279	220	294	268	420

The alternative *high raw material price* uses the same figures as in the main alternative with the exception that virgin pulp is valued at €151 per tonne (equalling €128 per tonne of liquid board containers replacing 0.85 tonnes of virgin pulp).

The alternative *no time costs for households* assumes that the time used for cleaning and sorting in the household sector has no alternative value, i.e., the cost is set equal to 0. It also assumes that the households only use cold water when cleaning the containers. Thereby the only cost for households occurs in those cases where the delivery system requires containers to be transported to a central recycling station. Using a higher time cost for households would strengthen the results from the first calculation, i.e., make recycling even more unprofitable as compared to other waste treatment options. A higher time cost can be justified based on the fact that the cost reported in Bruvoll et al. (2000) is very low.

The alternative called *best case for recycling* uses high environmental costs, old technology for landfilling and incineration, new technology for sorting of waste paper, high prices for virgin pulp and no costs, except for transportation, in the households.

In all the alternative calculations energy recovery has the lowest net social cost, whereas either mixed collection or delivery system for material recovery has the highest social costs. It is only in the last alternative, "best case for recycling," that recycling comes out better than landfilling, whereas incineration without energy recovery has approximately the same net costs as both collection systems.

Comparison with Life Cycle Analysis

An ordinary life cycle analysis (LCA) would only include those environmental aspects from the CB analysis that constitute the external effects included in the analysis. We have therefore constructed an LCA alternative where we consider only the environmental costs for each alternative plus the net extra transportation that recycling incurs. The net extra transportation is the transportation costs from households to Hurum minus estimated transportation costs for virgin pulp to Hurum, and it is estimated to be €13 per tonne of liquid board containers. The result is presented in Table V.

The calculations are made using both normal (that is, the most likely) and high environmental cost. For energy recovery the different prices refer to, respectively, coal-fired and gas power as the

TABLE V
Environmental and Transportation Costs for Liquid Board Containers. € per Tonne. 1999

	Landfill	Incineration	Energy recovery[1]	Collect	Delivery
Normal	138	86	–18/–17	–16	17
High	289	106	37/–8	–65	–43

[1] Present technology/New technology (BAT and gas).

marginal energy source. Using normal environmental costs, energy recovery seems to have the same environmental costs as recycling by a collect system. This result is in line with many LCAs of recycling systems, where the results often hinge on the energy source being replaced when incinerating waste, see for instance Finnveden and Ekvall (1998). Using high environmental costs, both recycling options prove to be more environmentally friendly than the other alternatives.

It should be pointed out that an LCA usually handles more detailed environmental data than does a cost-benefit analysis, but this does not necessarily hold for our study where we base the environmental costs on rather detailed data. Adding more detailed data about emissions would probably not alter our conclusion.

Our result enlightens one of the weaknesses of LCA, i.e., that it is incapable of distinguishing between systems with different costs, but with equal environmental performance. However, when prioritizing among and designing policy measures it is essential to know the costs associated with the different measures, this in order to achieve the policy objectives at the lowest possible cost, i.e., for the policy to be cost-effective.

DISCUSSION AND CONCLUSION

Our cost-benefit analysis shows that the present recycling system for liquid board containers in Norway has a substantially higher net social cost than do the more traditional disposal options, that is incineration and waste dispoal sites. The net costs in 1999 of recycling 7,500 tonnes of liquid board containers, and thereby avoiding incineration and landfilling, is estimated to equal €3.5 million. The environmental gain, which is included in this figure, is valued to be €0.55 million. An environmental policy that has such high costs, and gives such a small environmental gain, cannot be considered to be cost-effective. How can material recycling of liquid board containers then be defended? Often used arguments are: the recycling systems are new and large start-up costs must be accepted; recycling activities in the households are a way to make people more aware of the environment; and recycling of liquid board containers is just one part of a larger recycling system and should be analysed in a broader perspective. Below we will discuss these arguments in more detail.

Large Start-Up Costs

Our study concerns only one year, and we cannot for certain say that the net cost of the recycling system in 2003 equals the costs in 1999. An earlier study by a Norwegian consultancy shows that the costs for the recycling systems for packaging materials have been reduced between 1996 and 1999 (Hjellnes Cowi, 2000). It might be that the administrative costs, and especially the costs for advertising and information campaigns, will be reduced over time. As people get more used to sorting, they need not be reminded so often. Our study reveals that the costs incurred at NR is the largest cost factor, but reducing these costs to zero does not alter the conclusion. It has also been argued that the sorting costs will be reduced over time, especially in the case where liquid board containers are mixed with other waste paper. This argument is difficult to assess. But one should be aware that the organizational and technological improvements that are leading to reduced costs might happen also in ordinary waste handling.

Learning

The proponents of recycling often stress the educational motive as a defence for high administrative costs, meaning that we must be willing to pay a price today in order to educate people to act in a more environmentally friendly way. The latest survey concerning attitudes towards the environment performed through the International Social Survey Programme, ISSP 2000 Module on Environment, shows that in Norway people were less concerned about the environment in 2000 than they were in 1993 when a corresponding survey was performed (Skjåk, 2001). The share of people who sort different waste fractions has increased considerably from 1993 to 2000, but fewer are willing to reduce their living standard in order to protect the environment. Maybe the time perspective is too short to give any effects on total environmental performance, and that the learning need more than a few years to take effect, but it might also be the other way around. By sorting waste you might believe that you have done "your part of the job."

The Total Recycling System

It has also been argued that one should not study recycling of liquid board containers in isolation, but as a part of a bigger recycling system. But the study by Hjellnes Cowi (2000) concludes that almost all recycling of packaging waste from households incurs net costs, with the exception of cardboard and plastic. However, also for these materials energy recovery is more profitable. Based on these figures one cannot argue that the other parts of the recycling system are so profitable that they can "pay" for the recycling of liquid board containers. On the other hand, recycling of all packaging material might reduce the costs of ordinary disposal services, as for instance one might reduce the numbers of pick-ups. Recycling also reduces the amounts going to disposal sites and incineration, and might therefore reduce the costs of investing in new capacity in such plants, see e.g., Highfill and McAsey (2001) for a discussion of this. To be able to analyse the total costs a much broader study of the whole waste handling system is needed.

Environmental Costs

Our calculation is based on "best guess" estimates of the environmental costs, and it can be argued that these are not the true costs. Estimates of environmental, or external, costs are rough benchmark values and not "scientifically exact" figures. Nevertheless, they can be used as a basis for political action, since the estimations we have used conform to the best practice available, and they are therefore accurate enough to reflect the order of magnitude of external costs and to indicate the direction policies should take.

A comparison of estimated environmental costs in Vennemo (1995) and ECON (2000), both studying costs in connection with waste handling, shows that some substances have higher estimated costs in the latest study, whereas other substances are actually estimated now to have lower environmental costs. The alterations in estimated costs are mainly due to new knowledge about the actual harm caused by the different substances. One can therefore not state that the true environmental costs, if these were possible to estimate, would in every case be higher than the estimated costs used in our study.

NOTES

1 Personal communication with Sveinar Kildahl, Norsk Returkartong, 2001-03-15.

2 "Spesifisert oppgave over virkesimport I FM3UB (Specified list over import of timber in m^3)"; fax from Truls Bruu, Prosessindustriens landsforening (The Federation of Norwegian Process Industries), 2001-05-14.

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