Efficient glass and metal waste management system in Finland, conceptual study

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Keywords: waste management; environmental impacts; recycling; reuse; logistics

ABSTRACT

In waste management, it is essential to reduce the total amount of wastes and also to enhance reuse, recycling, and utilization of waste. The main goal of this study was to formulate and assess a life cycle model for the collection of container glass with household metal waste in Finland. The benefit of using Life Cycle Assessment (LCA) in understanding waste management systems is that it provides a comprehensive view of the processes and impacts involved. Our study includes different collection scenarios, where flows of materials and energy in the production, collection, purification, and use of recycling glass as a secondary material were studied. Recycling is widely assumed to be environmentally beneficial. Nevertheless, it is commonly forgotten that collecting, sorting, purification and processing of materials into new products also have environmental impacts.

The case study considers both ecological and economic aspects of waste management. It includes current systems, proposed collection systems, as compared to a system where no glass container collection is provided. According to the result, recommended collection system for container glass combined selective household system supplemented with municipal (public) collection system. The result is found to be also useful for decision-making in communities similar to the case study.

Glass packages and waste treatment in Finland

Today, recovery targets for packaging materials are defined by the EU. In Finland, the collection and recycling rates for recycling glass is now higher than EU requirements, but after December 2008 the requirements will tighten. The recycling rates for glass containers are achieved by refund and refilling systems, by using glass cullet in production of new container glass, and in the glass wool industry. Although this system is functioning quite well, changes are required to improve collection rates and logistic efficiency in municipal collections.

Currently, approximately 308 800 tons of glass containers are managed in Finland, with approximately 241 400 tons being refilled [1]. It is estimated that approximately 70 000 tons of glass containers will in the future be placed on the market and available for management options other than refilling. Annually 40 000 tons are currently recovered for the production of new products or as land fill. This means that annually at least 30 000 tons are still without any use and the terminal point for those is a dumping place.

Glass package collection in Finland is organized around a deposit system. Non-deposit glass is arranged through municipal collection systems. The municipal collection systems are now very small, collecting only ~10 000 tons/year. There are various reasons why the municipal collection rates are low:

- The population density in Northern part of Finland is very low which makes collection and utilisation not efficient,
- The demand for recyclable glass is limited,
- The collected glass contain impurities, limiting potential uses, and
- The glass industry has seasonal needs for certain type of glass, which may not be available.

If the collection is efficient and more glass packages could be collected, the raw-materials utilization could be improved and environmental impacts caused by intensive energy use in glass industry could be lowered. As follows, two types of assessments were performed. The first assessment focused on the collection system and the second focused on the life cycle of collection and utilization.

Collection System Assessment Process

In VTT's theoretical study [2], the Finnish glass package collection system was analysed using three different collection models: collection near shopping malls, a separate public collection system, and collection with other household waste management. The VTT study found that collection with other household wastes was superior. Thus, to find the best household waste management-based approach, a case study was arranged in the select districts of Helsinki metropolitan area. The inhabitants from multi-storey houses with more than 20 apartments were invited to the case study. This case study included 583 properties, 26 000 apartments and more than 40 000 inhabitants. The household collection was organised only for the bright glass because it is easier to utilise it. Also the present collection system was available for bright and colour glass.

Data collection was implemented in two phases. During the first phase, lasting six months, all the collection bins (240 litres) were emptied once per month, as depicted in Model 1 of Figure 1. As there were altogether 634 cans, eight working days were needed per month, since one driver could handle approximately 80 cans during one working day. Very soon it was found out that most cans were almost empty when the collection took place, and only less than 10 % of the cans were tolerably full.

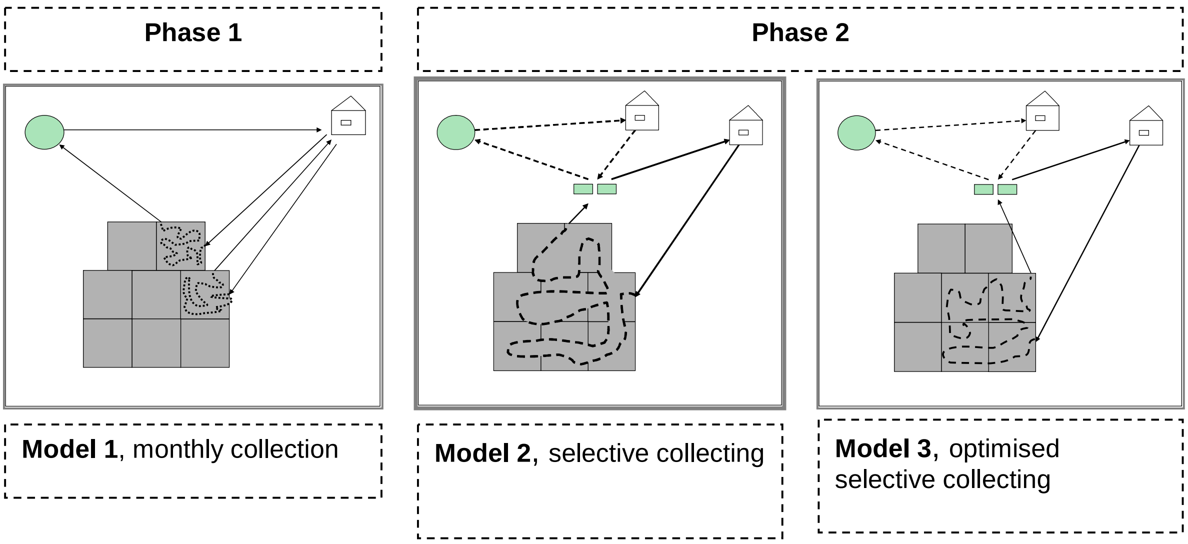

Figure 1. Collection models studied.

As the Model 1 appeared uneconomical, the Model 2 ("selective collecting" as depicted in Figure 1) was suggested. The idea of Model 2 was to travel the full route stopping only to collect bins that were half or more full. To develop Model 2, blocks were classified into 7 groups by assuming that big blocks with many inhabitants will produce more waste than smaller ones. This assumption proved to be true enough (correlation > 0.75). Thus, the classification was done so that the blocks were divided in groups according to an estimated collecting quantity per year.

Table 1 below shows that 48 blocks out of 634 belong to Group 1. These bins should be emptied every month. Group 2 consists of 70 blocks to be emptied every other month. Because of the need for a steady collecting system, Group 2 was divided among two months, meaning 70/2 = 35 bins per month (see column 3 of Table 1). Following this logic in all groups, it can be seen from Table 1, that instead of 634 collections (Model 1) only 176 collections were needed. Finally, Model 2 was refined to form Model 3 (see again Figure 1) or "optimised selective collecting" in which the total area has been divided into two parts. The first part will be collected selectively first and after that the second part, with a time difference of a half month. This enables that if there are some critical objects, the cycle of emptying is short enough.

Table 1. Classification of the blocks and emptying need per year.

Group	Need / year	Blocks total	Blocks / month
1	12	48	48
2	6	70	35
3	4	60	20
4	3	49	13
5	2.5	73	15
6	2	188	32
7	1	146	13
Total		634	176

To assess each collection model, the wheeling distance and costs were estimated. The estimation of wheeling distance was divided into four parts: collection, transfer, storage, and final transport. Collecting includes only the wheeling distance during the collection. Transfer includes the distance to the starting point and the return drive. Additional kilometres were required in Models 2 and 3 as the intermediate storage was located off route. Trucking to the destination is the distance from the collection area to the final destination which was the waste treatment plant “Ämmässuo” near Helsinki city (at a distance of about 20 kilometres).

Table 2 shows that the Model 1 requires total a wheeling distance of 7700 kilometres, Model 2 requires about 3260, and Model 3 only 2700 kilometres. It must be noted that all three models have also some differences. Next, fuel consumption was measured and partly estimated for each of the four parts of the wheeling distance. It was found that the consumption of fuel is clearly bigger in Model 1 than in the two other models. The difference between Models 2 and 3 is relatively small. Table 2 shows that the largest differences come during collection. As the fuel consumption in collection work is relatively high (varied between 75 and 100 litres / 100 km), the difference can be evaluated as relevant.

Table 2. Wheeling kilometres in different models.

Wheeling kilometres / year	Model 1	Model 2	Model 3
Collecting	2346	1946	1380
Transfers	3570	1050	1050
Additional transfers		90	90
Trucking to destination, return	1785	175	175
Total kilometres / year	7701	3261	2695

The cost analysis was also done in four parts. The analysis was based on estimated hourly costs and measuring the time needed in 7 phases during collection work: driving and handling the car, walking, collection, checking the contents, emptying, the empty can return, walking back and documentation. All models form two circles. In the first circle, the driver starts his work from the depot and transfers to the starting point of the collection work. After collecting he unloads (if needed) the unit at the intermediate storage and returns back to depot. Only when the intermediate storage is ready, the transportation to the final destination will be put in the practice.

As shown in Table 3, the analysis proves that Model 1 is clearly more expensive than Models 2 and 3. The difference between Models 2 and 3 are smaller, but differences exist. Thus, based on the assessment of the collection system wheeling distance and costs, Model 3 seems to be both environmentally and economically the best alternative.

Table 3. Collection costs for different models.

Collection costs / year	Model 1	Model 2	Model 3
Collection costs	44 625	15 000	14 063
Transfer costs	4 781	1 406	1 406
Additional transfer costs		469	469
Trucking costs	3 188	313	313
Total costs € / year	52 594	17 188	16 250

Life cycle environmental issues in glass packages collection and utilisation

LCA for glass container *collection and utilisation* was arranged by studying three scenarios: (1) the present state, (2) a rationalisation with collection based on Models 2 and 3 and utilisation for the production of new product, and (3) a scenario where no extra glass container collection was provided. The LCA includes flows of raw material and energy in production, collection, and purification of container glass. Scenarios 1 and 2 also include utilisation of glass waste as secondary material in the container glass production and glass wool production. Environmental profiles for the scenarios were calculated using Finnish industry data (for the glass container and glass wool production), VTT databases (for transportation LIPASTO-2005 [3]), and other literature data (mainly for raw-materials) as needed.

Present recycling glass collection is arranged by public collection system (P) were colour separation for bright- and colour glass is used. Improved glass collection for bright glass, was organized as Selective collecting model (based on Models 2 and 3 above) with the connection to the household (H) waste systems. At the same time, metal collection was organized in connection to the household waste system. As the metal and glass collection was organised by same waste management company and by same vehicle, it enabled us to allocate environmental impacts of collection to the glass and metal. The allocation was made on the basis of the volumes collected, measured for each trip over the 12 month study period. Typically, allocation was approximately half to each material. The overall magnitude of environmental impacts was dependent on collected glass and metal amount, fuel consumption in waste collection (minimum, average or maximum over the study period). Figure 2 shows environmental impacts separately for household system (H) and public collection (P) but the recommended system in Finland could be the combined system where both systems are used.

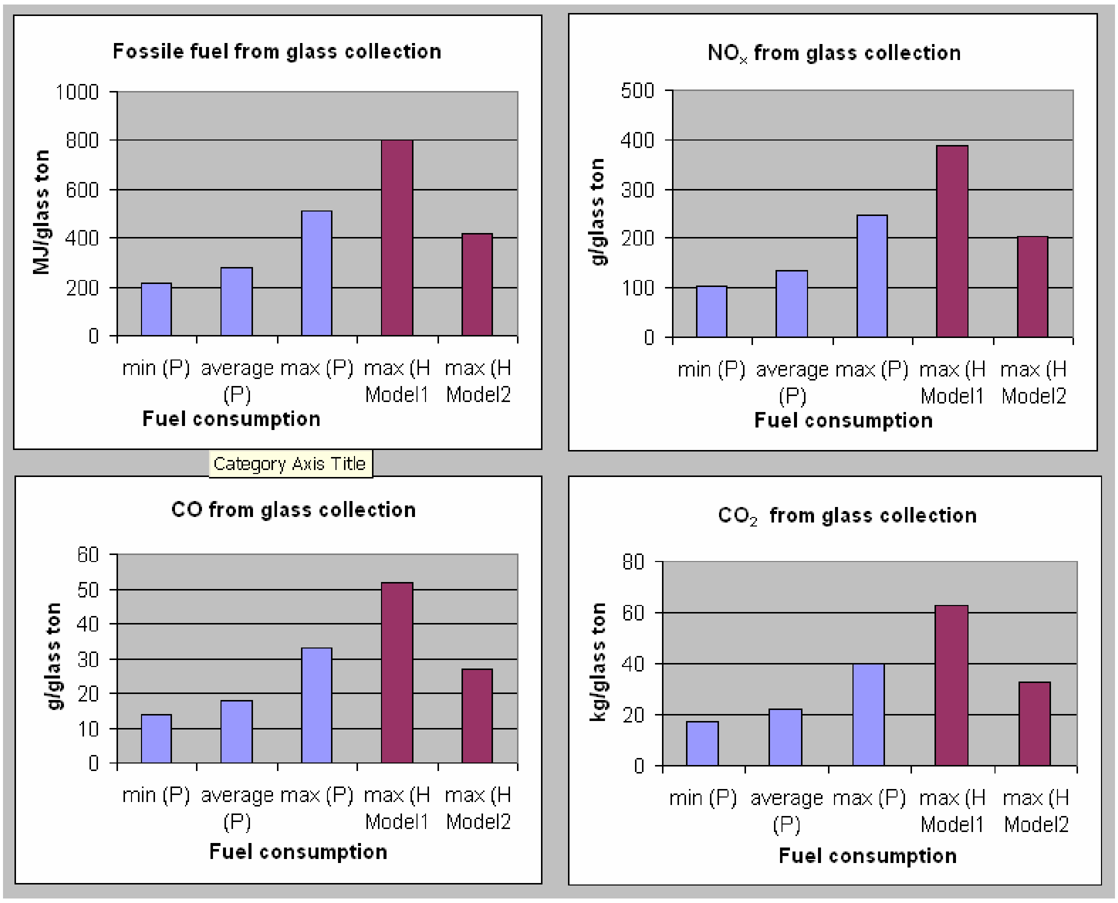

Figure 2: Environmental impact, fossil fuel, NOx-, CO- and CO2- emissions, from glass collection, in local/public system (P) and household (H) waste systems. The parameters plotted against the fuel consumption during collection (minimum, average or maximum). The allocation between metal and glass was used in the household waste systems.

Recycling glass utilisation (container glass production and wool production)
The environmental problems in glass industry are high temperature, energy intensive processes, and emissions from production. Especially nitrogen, sulphur dioxide, carbon dioxide, and oxides of nitrogen emissions are problematic. The greatest environmental pollution arises from the melting activities. The use of cullet will significantly reduce energy consumption, because the chemical energy required to melt the raw material has already been provided. As a general rule each 10 % increase in cullet usage results in an energy saving of 2 – 3 % in the melting process [4]. It is found that environmental impact of glass industry is decreased by using recycled glass. For example, when 60 % of recycling glass is used, the glass container industry could lower energy consumption up to 20 %, CO_2 up to 26 % and save natural raw-materials up to 50 – 70 %.

However, these savings are not currently realized, because there is an overall availability problem of certain types of recyclable glass. The amount of glass cullet used in the production of glass containers in Finland is now ~40 % and in the wool industry ~70 %. If the proposed collection system will be taken into use the availability and utilisation of container glass would grow and environmental pollution could be decreased. Figure 3 shows the decrease in environmental impacts from the glass collection and utilisation compared with the case where no collection and utilisation was provided.

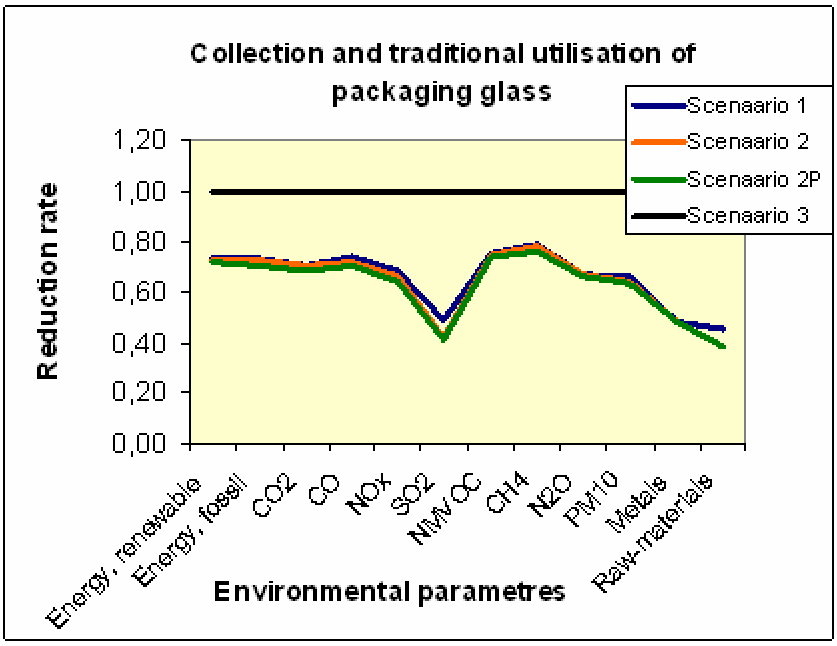

Figure 3: Collection and utilisation of packaging glass compared to the scenario 3 where no collection and utilisation provided (Scenario 1 - present stage, Scenario 2 and 2P - improved collection; "selective and optimised collecting models" and Scenario 3 – where no collection and utilisation was provided).

Conclusions
The glass collection analysis shows that it is both environmentally and economically better to carry out collection using the "selective collecting model" or its modification "optimised selective collecting model" rather than to collect every bin regularly (Model 1). Our estimation is that the reduction in both wheeling kilometres and collection costs will be more than 60 %.

To be able to collect the cans selectively, classification of blocks are needed. As the correlation between the outcome and amount of inhabitants is relatively high, the classification can be done by using quite easily procurable data. More sophisticated classification can be done by using population profile data including families with children and elderly. The testing suggests that relatively robust results can be achieved by using simple data.

The planning of the collection route has to be done carefully. In our empirical test, this was carried out by the driver. As some critical mistakes occurred (several exceeding cans), more developed methods than manual planning were recommended, but not tested during the empirical test.

The Model 3 suggests that the area can be split in two parts and thus allows organising the collection in two phases. As the population in the total area was about 50 000 inhabitants, we concluded that the optimum size of the population in an area is about 25 000 inhabitants.

It is known that the glass recycling saves natural raw-materials and lowers the total amount of waste. Recycling is widely assumed to be environmentally beneficial. Not only logistic management but also, sorting, purification and processing of materials into new products have environmental impacts. Because of that the whole process should be studied before evaluating the reasonability of the recycling systems. The recycling is meaningful when product recycling process itself does not produce environmental burdens more than when natural raw-materials are used.

Present, public glass collection system is beneficial, but the collection rates remain annually small. The glass package collection from the household system increases the collection rates almost three times, but also the environmental impacts are increased. It is shown that when the collection logistic is organised more efficiently, also environmental burdens could be lowered.

The use of recycling glass in energy intensive glass industry lowers the total energy amount, release of combustion gases and emissions. When recycling glass is used in the production of mineral wool or container glass the use of the natural raw-material amount could be lowered up to 50 %. Substitution of natural raw-materials with recycling glass decreases especially CO_2 emissions, because energy consumption is smaller and there are no chemically bounded CO_2 emissions emitted from recycling glass. In case when using natural raw-materials like sodium carbonate, soda and dolomite the energy and CO_2 consumption increases.

In this whole system (collection and utilisation of glass packages) the environmental impact from glass collection is less than 10 % because of energy intensive glass industry. If there is sufficient amount of recycling glass available and it could be utilised in glass industry the reduction of environmental impacts is at least up to 20 – 30 %. There is still a potential for additional use of recycling glass in glass wool and glass industry. These targets can be achieved if a suitable amount of impurity free glass cullet would be available.

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