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Results and Experiences from Combined LCA and Economical Assessment of New Collection Scheme in the City of Copenhagen

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EXECUTIVE SUMMARY

During 2005 an evaluation of a large scale experiment on a new collection scheme in the City of Copenhagen was conducted. The experiment conducted was aiming towards investigating the efficiency and environmental sustainability for collecting single use beverage containers of plastic and metal in the City of Copenhagen. It was chosen to conduct the collection of the two fractions together with recyclable glass in the existing publicly placed bottle banks. Originally, the bottle banks were used only for collection of household glass. The aim of the evaluation was to conduct a state of the art decision support combining life cycle assessment (LCA) and economical assessment (EA).

Altogether the experiment covered 12,000 households and 31 of the city's 520 publicly placed bottle banks. The collected materials were transported to a treatment facility where they were manually sorted into eight sub-fractions. The sub-fractions were quantified by number and weight. The results of the experiment was used to scale up the experimental bring scheme to a system scenario for the whole system of Copenhagen. Five system scenarios were defined:

- **The reference system:** Collection of household glass in public bottle banks. No separate collection and recycling of single used beverage containers of plastic and metal. These materials are collected together with residual waste which is sent to incineration.
- **The experiment:** The citizens bring the single used beverage containers of plastic and metal to the existing bottle banks for recycling.
- **Scenario 1: Collect scheme** where the single used beverage containers of plastic and metal are separately collected in designated bins placed in the courtyards of the households.
- **Scenario 2**: **Public collection station**. The citizens bring their single used beverage containers of plastic and metal to public collection stations.
- **Scenario 3: Bring scheme with separate containers**. The citizens bring the materials to publicly placed containers for respectively plastic and metal. The containers are placed next to the bottle banks designated for household glass collection.

The efficiency and environmental sustainability of the scenarios where assessed using LCA, EA and a combined environmental and economical assessment. The LCA showed that scenario 1 was the most environmental profitable. However, at the same time the EA showed that scenario 1 also was the most expensive collection scheme. In order to establish considerable decision support the life

cycle assessment and the economical assessment were combined making the environmental efficiency measured in environmental units per € visible. Thereby, the experiment showed to be the most efficient system scenario.

The major methodological experiences drawn from combining LCA and EA are related to defining compatible system boundaries and how to deal with uncertainties when combining the methods. Application the LCA, EA and combined assessment showed to be a useful tool evaluating possible waste systems and schemes. However, in order to improve credibility of combined environmental and economical assessments further efforts has to be put into developing methods and procedures suitable for establishing the defining boundaries and constraints. Moreover further work on establishing common data banks for key figures and other experience data would be beneficial for the development of the method.

INTRODUCTION

The commission of the European Union is stressing a need for complementing the waste management hierarchy with further developed approaches. The process development should be inspired by a life-cycle approach. Furthermore, the Commission stresses that in addition to environmental impacts, economical impacts also should be considered, leading to a cost-benefit approach on prioritizing waste management initiatives (European Commission, 2003). A similar mindset is expressed in the national Danish waste management strategy. The strategy states that the waste management hierarchy is a blunt decision tool that has to be combined with other tools for successful evaluation of the correlation between economical costs and environmental impact (The Danish government, 2004).

In recent years there has been an increased demand for life cycle assessments (LCA) of waste management systems. The LCA is defined by common standards and there are an extensive number of studies from which experiences can be drawn and the know-how of LCA of waste management systems is extensive. However, for combined environmental and economical assessments (CEEA), the number of conducted studies still is scarce. Thereby, the presence of standardized assessment methods as well as common know-how is lacking. Obviously, such knowledge is crucial to the success for large-scale usage of CEEA. With point of departure in an experiment in the City of Copenhagen, the capital of Denmark with approximately 502,000 inhabitants, aiming to evaluate a bring scheme for co-collection of single use beverage containers of plastic and metal as well as glass, the aim was to conduct a state of the art CEEA. This paper elaborates on the methodological experiences of the conducted study. The study is described in R98 (2005) and Schmidt (2005).

EXPERIMENT

The experiment conducted was aiming towards investigating the effectiveness, efficiency and environmental sustainability for collecting single use beverage containers of plastic and metal in the City of Copenhagen. It was chosen to conduct the collection of the two fractions together with recyclable glass in the existing publicly placed bottle banks. Originally, the bottle banks were used only for collection of household glass. During the experiment additional fractions of plastic and metal were allowed in the bottle banks. To avoid unnecessary contamination of the recyclable materials, the plastic and metal fractions were limited to single used beverage containers. The experiment was carried out during the full year of 2004 and took place in two appointed areas, one situated in the city centre and the other one situated in a suburban area of the city. Altogether the experiment covered 12,000 households and 31 of the city’s 520 publicly placed bottle banks. The bottle banks included in the experiment were emptied every second week by a crane-equipped container truck and the collected materials were transported to a treatment facility. At the treatment facility the collected materials were manually sorted into eight sub-fractions, i.e. 1) steel and 2) aluminium beverage containers, 3) PE-HD and 4) PET beverage containers, 5) reusable wine bottles, 6) other recyclable glass materials, 7) residual plastics and 8) other residual waste. The sub-fractions are quantified by number and weight and thereafter sent to recycling or incineration.

Figure 1: Bottle bank used in the experiment.

Sorting guidelines was given directly by labels on the containers as well as by direct mail to the participating households before the experiment was initiated. The information directly to the households were followed by complementing information during November 2004, requesting the users to continue using the bottle banks for recycling of single used beverage containers of plastic and metal.

The results of the experiment was used to scale up the experimental bring scheme to a system scenario for the whole system of Copenhagen. In addition to collection of data from the experiment, data from the existing full bottle bank bring scheme was collected in order to describe a reference system to the experiment. Furthermore, based on the experiences of the experiment as well as the collected data from the existing bring scheme three other possible collection scheme scenarios were sketched. Thereby, there were altogether five systems or system scenarios upon which the LCA, economical assessment (EA), and CEEA could be based upon. These system scenarios were:

- **The reference system:** Collection of household glass in public bottle banks. No separate collection and recycling of single used beverage containers of plastic and metal. These materials are collected together with residual waste which is sent to incineration.
- **The experiment:** The citizens bring the single used beverage containers of plastic and metal to the existing bottle banks for recycling.
- **Scenario 1: Collect scheme** where the single used beverage containers of plastic and metal are separately collected in designated bins placed in the courtyards of the households. Household glass is collected as described for the reference system.
- **Scenario 2**: **Public collection station**. The citizens bring their single used beverage containers of plastic and metal to public collection stations. Household glass is collected as described for the reference system.
- **Scenario 3: Bring scheme with separate containers**. The citizens bring the materials to publicly placed containers for respectively plastic and metal. The containers are placed next to the bottle banks designated for household glass collection.

METHODOLOGY

The purpose of the evaluation of the experiment is to provide high quality and relevant decision support to the decision makers in the sphere of waste regulation in the City of Copenhagen. The most relevant factors in such decisions are presumed to be of economic and environmental concerns. In the specific case of evaluation of the experiment it was a common interest by the City of Copenhagen and R98 providing better decision support in the evaluations of projects and experiments. The environmental part of the evaluation is performed as an LCA; i.e. an evaluation of the environmental exchanges and potential environmental impacts from the point where the waste is being generated throughout its life cycle through its final disposal or recycling. This includes collection, sorting, treatment, recycling-processing and any displaced primary material. The economical assessment (EA) is performed on the same system but with a more limited system boundary only covering the processes which are directly related to the economic sphere of the City of Copenhagen. The definition of system boundaries may have significant effect on the outcome of the LCA as well as the EA, and thus in particular on the CEEA. Therefore, definition of system boundaries is further discussed in relation to methodological experiences in section 5. The system boundaries for the two assessments are illustrated in figure 2. The functional unit in the LCA and EA is defined as: *Disposal of the potential of beverage packaging waste of plastics and metal and the potential of glass waste from households in the City of Copenhagen in 2004*.

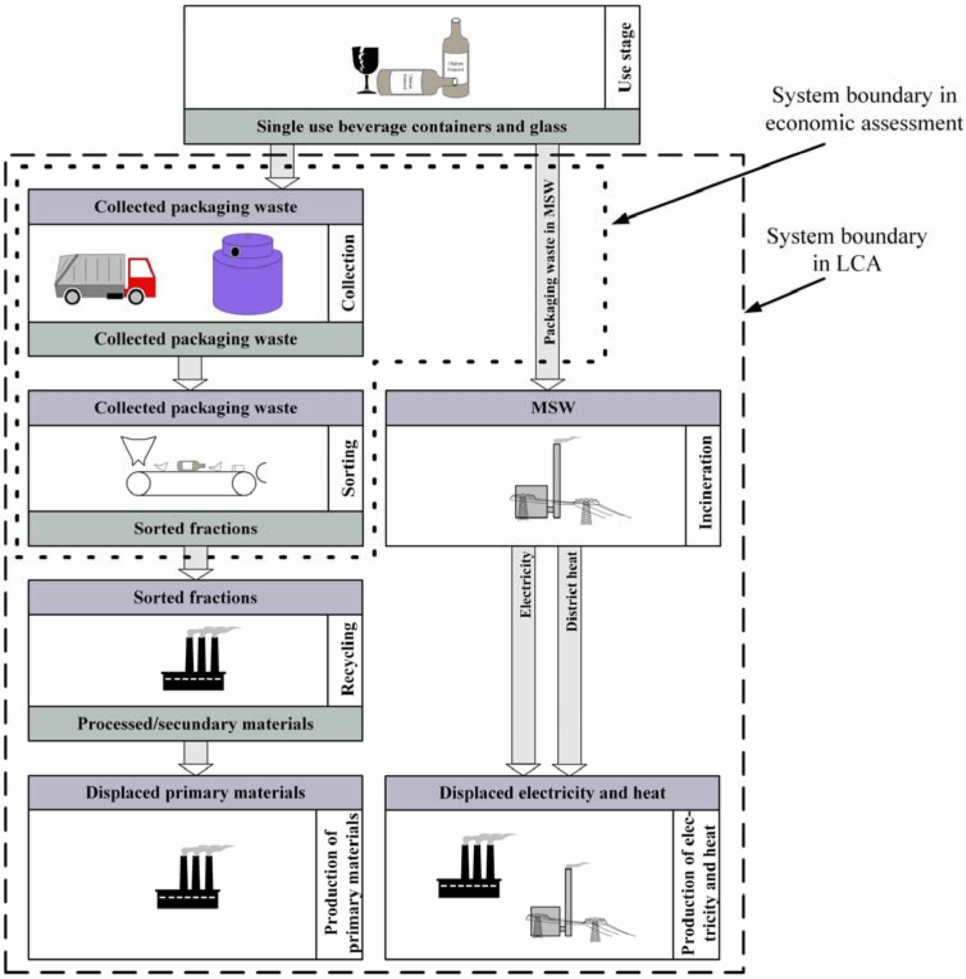

Figure 2: System boundaries.

Regarding the functional unit, the focus was initially on the amount of plastics and metal that could be expected to be collected with the system defined as the experiment. However, during the evaluation it appeared that there was a demand for additional scenarios where more plastics and metal could be collected. Furthermore, it appeared that the amount of more 'soft' packaging waste (plastic bottles and metal cans) in the bottle bank might have a positive effect by preserving glass bottles for being broken when put in the container as well as when the container was emptied and when the collected packaging waste was offloaded to the sorting plant. In order to capture the effects of all scenarios and side effects on glass bottles the functional unit was defined as the potential of packaging waste of plastics and metal as well the potential of glass.

Life cycle assessment

The LCA is conducted according to the ISO standards 14040-43. Furthermore, the system delimitation follows the recommendations in the Danish Methodology and Consensus Project (LCA Center, 2006). The Consensus Project prescribes adopting a consequential system delimitation, meaning that actually affected processes (marginal processes) should be included rather than averages, which is common in LCA. The method for system delimitation is described in Weidema (2003). Some of the consequences adopting this approach are that all electricity consumption is regarded as gas based (marginal in Europe) and recycling of collected glass take place in Southern

Europe because recycling of glass in Denmark is constraint by limited demand. This, despite the fact that some collected glass from the City of Copenhagen actually is send to recycling in Denmark. Data collection for waste flows has taken point of departure in registrations in the experiment and waste statistics. Inventory data on the single processes are to a large extent based on data from accounts on fuel consumption for collecting waste by R98 and the ecoinvent database (Ecoinvent, 2003) combined with specific data on the affected processes in Copenhagen and Denmark (heat and electricity, waste incineration, sorting etc.). The inventory result, i.e. the emissions related to the functional unit, consist of several hundreds different emissions. This is converted to a limited number of impact categories. The method used for that is the EDIP97-method (Wenzel et al., 1997 and Hauschild and Wenzel, 1998).

Economic assessment

The economic assessment have mapped all direct economic costs and benefits related to disposal of the waste defined in the functional unit for the City of Copenhagen, i.e. R98 for the year 2004. This includes costs for administration, buildings, waste collection material and its maintenance, personnel and diesel for R98. Furthermore, R98's costs and benefits related to disposal of the waste to third parties have been taken into account, i.e. benefits when the collected recyclable waste is sold for further processing and costs for delivering waste to incineration. The further, costs and benefits in the product chain have not been taken into account since they do not concern the economic sphere of the City of Copenhagen. The assessment has mainly been based on R98's economic account system. Furthermore, estimations on prices for disposal to third parties have been carried out in collaboration with the current parties.

Combined Environmental and Economic Assessment (CEEA)

As mentioned in the introduction the LCA process is well defined by common standards (ISO 14040-43) and there are an extensive number of studies conducted from which experiences can be drawn. The economic assessment is relative straight forward too. However, when it comes to combined environmental and economical assessments (CEEA) of waste management systems, the number of conducted studies is still scarce. In general two approaches can be adopted; integration or combination of the environmental and economic assessments. Integration means that the result is given in the same unit; often monetary. A common used approach for this is cost-benefit analysis where environmental effects are valuated (monetarized) and incorporated as economical costs. Adopting the combination approach, which can also be termed cost-effectiveness analysis, the results from the environmental and economic assessments are kept in their original units and the efficiency in terms of money per environmental saving (cost to achieve a defined goal) or environmental savings per cost (environmental performance for the costs) are assessed. This study adopts the last mentioned approach, where the most significant environmental savings from the different scenarios are compared to the costs.

4 RESULTS

Experiment

The amounts of recycled household glass and of single used beverage containers of plastic and metal during the experiment as wells as the estimated amounts for the five scenarios for the City of Copenhagen are presented in table 1.

Table 1: Collected amounts of material during the experiment and disposal of the waste defined in the functional unit for each disposal alternative and scenario.

Material fraction	Method of disposal	Experi-mental data (tonnes)	Estimated data for the scenarios (tonnes per annum) relating to the City of Copenhagen				
			Reference	Experiment	Collection scheme	Public collection stations	Bring scheme with separate containers
Reusable glass bottles	Reuse, bottle banks	79	1832	1832	1832	1832	1832
	Reuse, other systems	-	950	950	950	950	950
Crushed glass to recycling	Recycling	179	4024	4024	4024	4024	4024
	Incineration	-	4704	4704	4704	4704	4704
PET single used beverage containers	Recycling	0.452	0	24	72	5.3	18
	Incineration	-	566	542	494	560.7	548
PE-HD single used beverage containers	Recycling	0.995	0	1.8	5.4	0.4	1.4
	Incineration	-	42	40.2	36.6	41.6	40.6
Steel single used beverage containers	Recycling	0.364	0	8.9	26.7	2	6.7
	Incineration	-	207	198.1	180.3	205	200.3
Aluminium single used beverage containers	Recycling	0.241	0	5.9	17.7	1.3	4.4
	Incineration	-	138	132.1	120.3	136.7	133.6
Total	**-**	**260**	**12463**	**12463**	**12463**	**12463**	**12463**

The main source of uncertainty in the evaluation is considered to be related to defining the amount of collected materials in scenarios.

Life Cycle Assessment (LCA)

The result from the LCA is given as contribution to sixteen different impact categories. However in order to maintain the overview only the two considered most important impact categories are shown here; climate change and acidification. Table 2 summarises the results from the different assessed scenarios.

Table 2: LCA results. Scenarios compared to the reference situation.

Scenario	Climate change, tonne CO_2-eq.	Acidification, tonne SO_2-eq.
Reference situation	-1850	-13.5
Scenario compared to reference situation		
The experiment	-110	-0.40
Scenario 1 – Collection scheme	-230	-0.60
Scenario 2 – Public collection stations	-30	-0.10
Scenario 3 – Bring scheme with separate containers	-70	-0.20

It appears from table 2 that the present waste disposal of the potential of packaging glass, plastic and metal in the City of Copenhagen displaces significant potential environmental impacts (reference situation). This is primary due to reuse of glass bottles and recycling of broken glass. It also appears that all scenarios will have a positive effect on the environment. The internal ranking order of the scenarios is; 1) Scenario 1: collect scheme, 2) the experiment, 3) Scenario 3: bring scheme – separate containers for metal and plastic and 4) Scenario 2: public collection stations. The reason why the environmental savings in the scenarios are relatively small compared to the reference situation is, that the scenarios only concerns changes in plastic and metal fractions which constitute a small fraction compared to the glass fraction. The results shown in table 2 do not take into account that “soft” plastic and metal fractions may increase the reuse rate with up to 10%. If this is taken into account the experiment will displace 210 tonne CO_2-eq.and 1.6 tonne SO_2-eq. However, the measurements from the experiments cannot verify this; they can only render it as probable.

Economical Assessment (EA)

The results of the EA are presented in table 3 below. Apparently, there is a considerable difference in annual costs calculated for the different scenarios. The scenario using the public collection stations are the far most inexpensive scenario, followed by the experiment. Thereafter follows the bring scheme with separate containers for metal and plastic. The most expensive scenario is the one describing the collection scheme. The cost differences between the different scenarios can mainly be explained by the differences in the demand for personnel resources and thereby also in the need for operations management.

When comparing the cost effectiveness of the different schemes i.e. the cost per amount of collected tonne of plastic and metal the picture changes. The experiment scheme is the most cost-efficient scheme but it is followed by the collection scheme. The most inefficient scheme is the bring scheme with separate containers for plastic and metal and in between comes the scheme using the public collection stations. The major difference between measuring costs and efficiency evidently is that when measuring cost-efficiency the estimations of expected amounts of collected materials also are taken into consideration. Schemes providing a higher level of user service and accessibility are expected to enhance the amount of collected material per user. Therefore, a collection scheme as the one described in scenario 1, although encumbered with considerable annual costs of operation, can turn out to be quite advantageous when comparing cost-efficiency.

Table 3: EA results. Cost presented as additional costs compared to the reference situation.

Scenario	Total cost of the scheme (1000 € per year)	Cost per amount of collected metal and plastic (1000 € per tonne)
The experiment	260	6.4
Scenario 1 – Collection scheme	1063	8.7
Scenario 2 – Public collection stations	94	10.5
Scenario 3 – Bring scheme with separate containers	558	18.4

Combined Environmental and Economical Assessment (CEEA)

When combining the results of the LCA and the EA it is possible to calculate the environmental cost-efficiency of the different scenarios. The results, presented in table 4, show the cost-efficiency expressed as tonnes avoided CO_2-equivalents as well as tonnes avoided SO_2-equivalents per Euro. Once again, the internal ranking order of the scenarios is changed and is in relationship to environmental cost-efficiency; 1) the experiment, 2) Scenario 2: public collection stations 3) Scenario 1: collect scheme and 4) Scenario 4: bring scheme – separate containers for metal and plastic. The explanatory factors of the environmental cost-efficiency ranking are similar to those discussed above concerning the economical cost-efficiency. The difference between the analyses is a different approach towards the amount of collected materials.

Concluding on the results presented above the following observations can be made: If focusing on avoiding as much negative environmental impacts as possible in absolute terms Scenario 2: the collection scheme is to prefer, if focusing on finding the most inexpensive scheme in absolute economical terms Scenario 2: public collection stations are to prefer and if focusing on finding the most environmentally cost-efficient scheme the experiment scheme is to prefer.

Table 4: Result of the CEEA. Cost presented per avoided environmental effect.

Scenario	Cost of avoided climate change (1000 € per tonne avoided CO_2-eq.)	Cost of avoided acidification (1000 € per tonne avoided SO_2-eq.)
The experiment	2.4	650
Scenario 1 – Collection scheme	4.6	1772
Scenario 2 – Public collection stations	3.1	940
Scenario 3 – Bring scheme with separate containers	8.0	2790

METHODOLOGICAL EXPERIENCES

System boundaries

As described in the methodology section, system boundaries are crucial for the outcome of the LCA as well as the EA. It has shown to be of importance to be aware of where system boundaries in the LCA and EA are common and where they are not, see figure 2. One example is transport of plastic and metal to public collection stations in private cars in scenario 2. In the LCA the emissions from that transport is included while the costs related to this is not included in the EA. It is obvious that such emissions should be included in the LCA because the collect scheme would directly affect this transport. The argument for omitting this transport from the EA is that it does not affect the economic sphere of the City of Copenhagen; i.e. no extra fees have to be collected. In that sense the system boundary for the LCA is defined as total; all environmental relevant processes that are actually affected are included. But when it comes to the EA, the system boundary is defined by the purpose of the assessment; costs for whom? This is important to be aware of when interpreting the results from the CEEA, because the decision makers have to know who pays for the environmental benefits and which specific economic budgets will be affected.

Uncertainties

Uncertainties in the results from the LCA and the EA are assessed to be of some importance. The effect of the considered most significant uncertainties are all assessed in uncertainty analyses in the LCA as well as in the EA. Thus, these uncertainties are somehow well known and well described. However, when it comes to the CEEA the uncertainties from the LCA and the EA are adding up and at the same time the results are simplified and reduced in order obtain results that are easy to interpret for the decision makers. This means that the CEEA only includes the most significant and most robust described environmental impact categories (climate change and acidification), the reservations and uncertainties carried forward from the LCA and EA are not described at the same level of detail, and at the same time uncertainties may be considered as more significant than in the LCA and EA one at the time. Therefore, more emphasis should be given to sensitivity analyses on the level of CEEA rather than in the LCA and EA one at the time. But still care should be taken; neither LCA nor EA provides an entirely correct picture of reality and neither does the CEEA which is based on simplified results from the LCA and EA.

CEEA compared to CBA

Is the way to go CEEA or cost-benefit (CBA)? The two previous sections describe some potential significant sources to misinterpretation of the results from CEEA. Is the answer to adopt a cost-benefit approach in stead? It is important to be aware of the result from a CBA will be hard to find in real world economic budgets because it include direct economic costs as well as costs which are normally not incorporated in economy (valuated costs of e.g. environmental impacts, time spent by people to handle their waste etc.). Also there is lack of transparency of who “pays” the costs in CBA. The direct economic costs will primarily be paid via fees collected by the City of Copenhagen. But the indirect costs and benefits are spread out all over the world. Therefore, it may be hard for the decision makers to interpret the results of the CBA which is given as the sum of direct and indirect costs and benefits. Concerning the potential sources to misinterpretation of the results from CEEA, the same problems are present in CBA. However, uncertainty and sensitivity analyses are often presented on the aggregate level in CBA.

PRACTICAL EXPERIENCES OF CONDUCTING AND USING CEEA

Politicians and decision support

Considering the large amount of work done in order to improve the decision support for decision makers there has been surprisingly poor feed-back from the politicians who have used the CEEA. There may be several reasons for that; 1) the recommendation written by the public servants of the environmental protection agency of Copenhagen do not, by its limited extent, represent all aspects of new methodology and research behind the recommendation, 2) the distance between EU level objectives on waste management and objectives by Copenhagen and the single politicians is far; other, more near, problems than global environmental impacts and life cycle assessments determine the decision, 3) politicians have no or very little knowledge and experience using LCA and CEEA.

Application of CEEA

As it appears from the previous section it is the public servants in the Environmental Protection Agency who uses the evaluation reports (LCA, EA and CEEA) for writing a recommendation to the decision makers. That is important to be aware of. It is not even sure that the politicians see the results from the CEEA in terms of e.g. saved CO_2-eq per € spent on the scheme. Thus, the CEEA was not used as direct decision support tool for the decision makers, but as decision support for the public servants. Therefore the crucial is; how the CEEA has affected the public servants in the City of Copenhagen rather than it has affected the politicians. The question is then; does the CEEA provide the public servants with better information writing the recommendation and giving advice to the politicians? The experience here is that the evaluation containing LCA, EA and CEEA has been of great value. But still, the public servant’s common sense of practical implementation problems such as “space for containers” has same weigh as the results of the CEEA when writing a recommendation.

Another important lesson learned from the work with LCA and CEEA is that the learning process generates many other outputs than decision support related to that specific decision the evaluation was meant to support. One example of such surprising results was identified undesirable effects of exporting the collected recyclable waste for mechanical sorting abroad. Another example was identified relative large consumption of plastic for collection containers compared to the predicted amount of plastic that could be collected. In the first example it appeared that mechanical sorting abroad would result in that glass bottles, which in Denmark are reused, would be lost and recycled as broken glass in stead. This would result in a dramatic increase in the environmental impact from waste management of glass, plastic and metal in Copenhagen. In the second example it appeared that the bring scheme in scenario 2 were incinerating just as much plastic when the containers are disposed as the amount collected for recycling during the containers service life. This resulted in changed practise of disposal of collection containers in the City of Copenhagen, where containers at the end of their lives in the future will be sent to recycling in stead incineration.

The CEEA and the determining factors in decision making

The purpose of combining EA and LCA were to provide the best possible decision support focussing on the most important factors. However, as mentioned in the previous section, other factors as the ones of concern in the evaluation may turn out to be the determining factors during the political process. In the specific case, important factors which were not specifically included in the evaluation are; service for the citizen is weighted relatively high, space for new containers in back yards in inner Copenhagen competes with lawns and playgrounds, and placement of more collection containers in the urban landscape is in general considered to be aesthetical undesirable.

These examples underpin that even when applying the most comprehensive evaluation designs fulfilling the overall EU objectives on using LCA and following the waste hierarchy, it is not sure that this will constitute the determining factors in the decision taken. Therefore, an exhaustive examination of such 'killer assumptions' mapping different interest parties view on the design of the desired scenarios is important and may even save time for analysis of irrelevant scenarios at a later stage.

Another lesson learned relating to the determining factor in decision making is changing preconditions. Changes in or possibly upcoming crucial and less important preconditions have been identified. An example of a crucial precondition is the packaging fee on reusable glass bottles in Denmark. Payback of the money collected from this fee when bottles are reused ensures that there is an economical incentive for reusing especially wine bottles. However, there are ongoing debates whether this fee should be dropped. If the fee is dropped, more than half of the environmental benefit for collecting glass in Denmark would be lost. Also the possible effect of "soft" fractions of plastic and metal in the experiment preserving the bottles from being broken in the containers would have no effect. Less significant preconditions that have been changed during the experiment and evaluation period is the purchasers of collected waste for recycling and their location. Other possible purchasers mean other prices and other location means changed transport distances and thus emissions.

Project management and CEEA

An evaluation process that includes both an LCA and an EA as well as the combination of the two; the CEEA, makes some certain requirements to the project management. Normally, an LCA and an EA can be conducted separately by separate practitioners. But when the LCA and EA have to be combined in the end starting point, functional unit and system boundaries have to be continuously standardised and adjusted. Furthermore, it is a resource and overview demanding task for the project manager to communicate every assumption and change of assumptions. This often includes communication between the project manager, the practitioner of the LCA, the EA as well as the CEEA and the parties committed to approve preconditions and scenarios. In addition the nature of CEEA; to find the most cost effective alternative, intensifies the focus on alternatives. During the evaluation period there has been an increase in the need for assessment of new scenarios and uncertainty analyses. Initial these extra scenarios were included as less documented than the main scenario. But, when some attractive alternatives are communicated to decision makers the need for more documentation were further stressed.

CONCLUSION

The study shows that Combined Environmental and Economical Analysis (CEEA) is a useful tool to use in order to evaluate possible waste systems and schemes. The strength of the tool is that the well defined methodologies of the Life Cycle Assessment (LCA) and the Economical Assessment (EA) can be used to achieve a combined result without having to translate the environmental impacts into economical impacts, which is the case for cost benefit analysis. Thereby, the environmental factors still will be presented as environmental impacts, which enable political prioritizing between different environmental impacts and a transparency of the model. The CEEA tend to be more transparent and less infected by subjective evaluation than a Cost-Benefit Analysis (CBA). However, the method is demanding in terms of time and project management.

Therefore, it is important to secure that the results of the CEEA can be used in the political decision process, ensuring that the work reflects the decision maker's need for information. In order to fulfil these needs, it is important to prepare the CEEA carefully, with a certain focus on the boundaries and constraints of the analysis. Apart from defining the functional unit and the system boundaries it is also utterly important to define the constraints in correlation to factors such as customer service, aesthetics and the physical constraints of the city. These kinds of factors have been shown to impact the decision as much as the actual results of the CEEA and are therefore important to establish in order to secure an efficient CEEA process. Furthermore, it has been shown that uncertainties in the input data of the CEEA, especially concerning the amounts of collected material estimated for the investigated scenarios, has to be commonly established and accepted not to jeopardize the credibility of the CEEA. Therefore there is a need of using a combination of sensitivity analysis, key figures and other branch experience data as well as and complementing trials and experiments to secure the credibility of the scenario assumptions.

Therefore, in order to improve the acceptance and efficiency of the CEEA method, further efforts has to be put into developing methods and procedures suitable for establishing the defining boundaries and constraints. Moreover further work on establishing common data banks for key figures and other experience data would be beneficial for the development of the CEEA method.

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