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The Use of the LCA-IWM Tool to Assess the Sustainability of Waste Minimisation

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Abstract
National waste management systems are often evaluated by their ability to produce as little waste as possible or by their overall environmental impact. In this paper a methodology combining these two approaches is proposed. The Waste Management Ranking consists of the four criteria: Generation, Recycling Rate, Diversion from Landfilling and Environmental Impact.

1 Introduction
Governments and governmental organisations at local, regional, national and supra-national levels normally provide for waste prevention in their policies and legislation. For instance the German KrW-AbfG describes general waste management options in the so-called Waste Management Hierarchy. The most favored option therein is the avoidance of waste (Bilitewski et al., 2000). In the previously mentioned references to waste prevention ambitious targets for waste avoidance are often prescribed. The central problem is represented by the fact that the stakeholder who is most interested (and is indeed involved in the venture) in achieving the targets is simultaneously the one who has the least influence on the results. The other stakeholders, producers and consumers are characterized by a considerably higher potential for waste avoidance. Focusing on household waste it can be observed however that in practice avoidance produced both through product design and consumer behavior is not very significant. Moreover, producers and consumers seem to be hard to influence, as emphasized by numerous municipal waste management plans providing for rather non-quantitative and non-enforceable objectives with regard to waste avoidance. By far the more detailed section within the waste minimization chapter is concerned with recycling and recovery of produced waste. Waste minimization can namely be divided according to the two following terms:

- Waste Avoidance (or intrinsic waste prevention or quantitative waste minimization)
- Diversion from Landfilling (or recycling and recovery or qualitative waste

minimization)

In this paper a proposal for a comprehensive European ranking of national waste management practices, taking into consideration both their level of waste minimization and their sustainability, is provided. For the latter the so-called LCA-IWM Waste Management Assessment Tool will be used.

2 Materials and Methods

The proposed Waste Practice Ranking consists of four evaluation criteria, each of which express a different aspect of waste minimization. In the following the criteria and data used are described.

2.1 Generation

Rather than achieve a finely tuned system for the assessing of single waste prevention measures on a municipal level, the proposed Waste Practice Ranking aims at a national and, admittedly, coarser level of assessment. The first evaluation criterion is waste generation. The total amount of household waste generated in a country gives a rough indication of the success of waste avoidance policies. Needless to say, this parameter depends largely on the level of development of the national economy. The total amount of generated household waste is taken as a theoretical maximum of 1,000 kg/ capita. Thus a number between 0 and 1 is achieved, with 1 being the lowest possible amount of generated waste (0 kg/capita) and 0 being the ultimate case of a waste generation of 1,000 kg/ capita.

2.2 Recycling rate

The second criterion, the recycling rate, calculates the share of not otherwise avoided generated waste undergoing treatment in order to be re-used or used for other purposes. All treatment options classified as 'material recycling' are considered here. The share of selectively collected paper & cardboard, glass, metals, plastics & composites, biowaste and garden waste related to the total amount of generated household waste is expressed in a number between 0 and 1. A score of 1 indicates full recycling, whereas 0 stands for no recycling at all.

2.3 Diversion from Landfilling

In addition to the recycling of materials, numerous other ways of (pre-) treating waste exist, such as mechanical-biological pre-treatment and incineration of residual waste. Incineration of waste can be considered as energy recovery or as thermal disposal. In the Waste Practice Ranking this highly debated issue is avoided by focusing on the total amount of waste ultimately landfilled in the countries considered. The share of all waste not being landfilled is expressed in relation to the total amount of waste generated. A number of 0 stands for no diversion from landfilling at all, whereas an outcome of 1 means that no residues are stored in landfills. Parameters taken into consideration were the amounts of residual or mixed waste landfilled directly, as well as waste left over after pre-

treatment (low caloric MBP outputs or Incineration slag & ashes). Moreover, all residues of recycling operations destined to be conferred to a landfill were incorporated here.

2.4 Environmental Impact

Taken together, the aforementioned criteria provide a qualitative judgment of the considered waste management practices. No differentiation is made however, on the quantitative impact to the environment. In order to enable such an environmental impact assessment the LCA-IWM Waste Management Assessment Tool is applied. In the following the background of this tool and its use within the Waste Practice Ranking is explained in further detail.

2.4.1 Background of the LCA-IWM Waste Management Assessment Tool

Within the European Commission's Fifth Framework Program a project ('The Use of Life Cycle Assessment Tool for the Development of Integrated Waste Management Strategies for Cities and Regions with Rapidly Growing Economies' (LCA-IWM)) aimed at the development of tools to assess the sustainability of waste management in European cities, in particular cities from EU Accession Countries (Den Boer et al., 2005), was set up. The Project Consortium consisted of twelve Partners, both from the European States as well as EU Accession States. Within the project two decision-supporting tools have been developed: the Municipal Waste Prognostic Tool and the Waste Management Assessment Tool.

The Prognostic Tool enables, based on a minimum of user inputs, an accurate prediction of the generation of future waste amounts. A vital step in this process is the consideration of waste prevention measures and the quantitative impact thereof on the future waste amounts. Moreover, the recycling and recovery quota are predicted, based both on actual achievements in the city investigated and on targets deemed to be achievable for cities at a comparable socio-economic stage of development.

The Assessment tool enables the planning and assessment of waste management strategies. Up to four different scenarios can be created and compared. Using user-adjustable standard modules combined with user inputs the tool determines the impacts in the three aspects of sustainability: Environmental, Economic and Social Sustainability. The Environmental Assessment consists of an LCA-based evaluation of the environmental performance of considered waste management systems. Also the compliance with European regulations is assessed. Waste management systems are thereby divided into the sections Temporary Storage, Collection & Transport and Treatment & Disposal.

2.4.2 Application of the LCA-IWM Waste Management Assessment Tool

For the Waste Practice Ranking only the Environmental Assessment section of the LCA-IWM Waste Management Assessment Tool is applied. The Social and Economic sections on the one hand depend on a geographic location and on the other

require rather specific inputs. Neither of these demands can be met within the frame of the Waste Practice Ranking. In this case, the Tool is applied for countries as a whole, whereas it was initially designed for municipalities. Consequently, comparisons cannot for obvious reasons achieve particularly detailed results. The environmental impacts of Temporary Storage and Collection & Transport are not considered due to the fact that an excessive quantity of inaccessible or scarcely accessible data would be needed. The assessment focuses on the Treatment & Disposal of the collected waste only. Thereby an equal level of technology in the various treatment options is assumed. Moreover, plant specifications and user inputs are assumed to be the same for all countries. As a consequence, as an example all composting of waste is assumed to be done in installations equipped with a biofilter treating the exhaust air and operating with equal decomposition rates for organic compounds.

The LCA-based environmental assessment criteria of the LCA-IWM Assessment Tool provide an output in Inhabitant Equivalents (IE). Therein the environmental impact of the assessed scenario is related to the total environmental impact per capita for all human activities performed in the whole country throughout a one year period. For the sake of simplification (although it does not make any physical sense) the LCA-based indicators are weighted according to the differentiation of importance suggested by the German Environmental Agency and consequently added up (Giegrich et al., 1999). The used assessment criteria and their weighting factors are:

- abiotic depletion and photochemical oxidant formation = 1
- acidification, eutrophication and human toxicity = 2
- global warming = 3

Thus, the value obtained for IE is then related to the number of inhabitants of the considered countries in order to enable a fair comparison. The determined environmental gain (in IE/capita) is related to the highest amount obtained throughout the countries taken into consideration. Thus a number between 0 and 1 is achieved, with 1 being the highest achieved environmental gain (the environmental impact of waste management systems is generally positive, since the main resource of the system, the waste, is obtained 'for free', whereas primary resources and energy, with subsequent emissions, is substituted by secondary products). The LCA-IWM Assessment Tool determines both the Environmental Impact the Diversion from Landfilling indicator.

2.5 Used data

The proposed Waste Practice Ranking has first been tested by evaluating four countries at varying stages of development with regard to national waste management practices. Two countries with well established waste management systems but varying approaches were represented by The Netherlands and Germany. In the latter mixed packaging waste was collected, whereas in the former this

Tab. 1: Separately collected household waste fractions in European countries (1,000 tons)[1]

Country	Year	Paper & cardboard	Glass	Metals[2]	Plastic & composites	Bio-waste	Garden waste	Hazard-ous waste	Residual waste	WEEE	Bulky waste[3]	Total
Catalo-nia	2005	233	111	26	36	205	60	1	2.977	-	142	3,791
Ger-many	2004	7,740	3,100	746	1,254	3,661	4,172	1	15,558	52	2,589	38,873
Nether-lands	2005	1,144	338	2	7	1,362	406	35	3,958	71	716	8,039
Poland	2004	100	103	0	40	-	326	-	10,417	-	451	11,437

Tab. 2: Composition of household residual waste in European countries (%)[4]

Country	Year	Paper & cardboard	Glass	Metals	Plastic & composites	Bio-waste	Garden waste	Hazard-ous waste	Residual waste[5]	WEEE	Fines	Total
Catalo-nia	2005	14.8	5.6	4.2	13.1	39.5	11.6	0.0	11.2	-	-	100.0
Ger-many	2004	25.8	10.8	2.5	6.9	15.1	17.2	0.0	21.5	0.3	-	100.0
Nether-lands	2005	12	5	4.1	20	21.5	0.5	0.1	23.1	0.6	13	99.0
Poland	2004	20.3	8.5	5.0	21.5	23.9	2.4	0.9	3.4	-	14.1	100.0

1 Sources: Catalonia (ARC 2006), Germany (BMU 2006, GVM 2006), Poland (Ministerstwo Środowiska 2006) and The Netherlands (CBS 2007, SenterNovem 2006a, FNOI 2007). The division between metals and plastics & composites is based on the collection data for Spain in 2002 (Eurostat 2005) for Catalonia and on collection data for Lower Silesia in 2004 (Szpadt et al. 2005) for Poland.

2 Only packaging metals

3 Only residual bulky waste. Separately collected bulky wastes, e.g. iron scrap, are not considered.

4 Sources : Catalonia (Eurostat 2005), Germany (IFEU 2005, GVM 2006), Poland (Ministerstwo Środowiska 2006) and The Netherlands (SenterNovem 2006b). Data for Catalonia based on generation data for Spain in 2002. Data for Poland and Germany partly based on generation figures.

5 Including textiles. These are not considered in the separately collected waste quantities, since their collection is partly done by NGOs

Tab. 3: Generated household waste in European countries (calculated, 1.000 tons)

Country	Year	Paper & cardboard	Glass	Metals	Plastic & composites	Bio-waste	Garden waste	Hazardous waste	Residual waste	WEEE	Bulky waste	Total
Catalonia	2005	675	277	150	427	1,380	404	2	334	0	142	3,791
Germany[6]	2004	9,364	3,902	904	2,500	5,471	6,234	2	7,804	104	2,589	38,873
Netherlands	2005	1,619	536	164	799	2,213	426	39	1,429	95	716	8,035
Poland	2004	2,214	992	521	2,280	2,486	576	93	1,824	-	451	11,437

Tab. 4: Treatment methods for biowaste and residual waste[7]

Country	Year	Inhabitants	Biowaste		Residual & bulky waste			
		(1.000)	Digestion	Composting	Landfill	Incineration	MBP aerobic	MBP anaerobic
Catalonia	2005	7,084	27.4%	72.6%	70.7%	22.7%	0.0%	6.6%
Germany	2004	82,501	10.0%	90.0%	35.8%	51.2%	8.6%	4.3%
Netherlands	2005	16,306	3.0%	97.0%	1.1%	66.0%	28.0%	4.9%
Poland	2004	38,175	0%	100%	99.6%	0.4%	0%	0%

6 Amount of residual waste fitted to the total amount of generated waste.

7 Sources: Catalonia (ARC 2006, 2007), Germany (Statistisches Bundesamt 2006, BMU 2007), Poland (Ministerstwo Środowiska 2006) and The Netherlands (Werkgroep Afvalregistratie 2006, SenterNovem 2005). Division between aerobic and anaerobic MBP is estimated only.

was not the case. Furthermore, the German situation recorded for the year 2004 continued to show a fair share of residual waste being landfilled directly. As a region being on its way to having a fully developed waste management system, Catalonia was chosen. The current waste management system applied in Poland mainly consists of direct landfilling of mixed waste. Although the data required are comprised of waste statistics alone (since social and economic assessments were not considered) it was a difficult task to identify acceptably reliable and recent data throughout the European community. Thus, the required data were compiled from various national sources to which a number of assumptions had to be applied. Tables 1 to 4 present the assumptions applied and data calculated for household waste collection, residual waste composition, total generated household waste and treatment options for residual wastes and biowaste.

3 Results

Based on the methodology, data and assumptions presented in chapter 2 the intermediate results as shown in table 5 were achieved for the considered countries.

Tab. 5: Indicator results for the Waste Practice Ranking of four European countries

Country	Generation (1.000 tons)	Generation (kg/cap)	Recycling (1.000 tons)	Final Landfilling (1.000 tons)	Environmental Impact (IE)
Catalonia	3,791	535	672	2,223	-278,046
Germany	38,873	471	20,726	7,500	-7,459,477
Netherlands	8,035	493	3,365	866	-720,647
Poland	11,437	300	569	10,387	-112,362

Using the intermediate results from table 5, the indicator scores of the four evaluation criteria can be calculated. The results of this calculation, as well as the resulting values for the Waste Practice Ranking (which consist of a multiplication of the four considered scores) are shown in table 6. The Waste Practice Ranking is built up in the same way as the Environmental Sustainability Index and the Environmental Performance Index of Yale University (Esty et al., 2005, 2006).

Tab. 6: Indicator scores for the Waste Practice Ranking of four European countries (multiplication calculation method)

Country	Generation	Recycling Rate	Diversion from Landfilling	Environmental Impact	Waste Practice Ranking
Catalonia	0.46	0.18	0.41	0.43	0.0148
Germany	0.53	0.53	0.81	1.00	0.2276
Netherlands	0.51	0.42	0.89	0.49	0.0926
Poland	0.70	0.05	0.09	0.03	0.0001

Considering the resulting indicator values shown in table 6, a number of interesting observations can be made. The total generation of household waste shows higher values (meaning lower generation) for the considered countries with economies that are still not at the level of the considered Western European countries. As for the recycling rate, it can be clearly seen that Germany and The Netherlands, both having long established waste management systems, show the highest score. A similar pattern can be observed for the diversion of generated waste from landfilling. With regard to the years considered The Netherlands featured the highest score. German findings are referred to the year 2004; the subsequent introduction of the German ban on landfilling of non-pretreated waste in June 2005 will produce a considerable effect in future years.

The environmental impact shows a surprisingly high score for Catalonia and a low one for The Netherlands (as compared to the recycling rate and diversion for landfilling). For a minor part this is caused by the higher amount of waste generated per capita in Catalonia: the higher the amount of waste treated and disposed of, the higher the resulting environmental impact score (indicating a higher environmental gain achieved by the waste management system). Another reason lies within the national energy supply systems. In the LCA-IWM Assessment Tool the national electricity production mixes are considered. As a consequence, 1 kWh of electricity produced by the waste management system will take the place of another 'type' of primary produced electricity with subsequent environmental burdens. In this case The Netherlands is at a disadvantage, having a relatively 'clean' electricity production (being a net natural gas producer). The production of heat has been assumed equal for all considered countries, since it is hard to say what primary produced heat may be taken as having been substituted. Lastly, the low collection results obtained for metals and plastics & composites for The Netherlands in comparison to Catalonia and especially Germany must be accounted for. Indeed, also the amounts of paper & cardboard, glass and biowaste per capita found in The Netherlands are considerably lower than those obtained in Germany.

The resulting Waste Practice Ranking reveals a remarkably diverse picture with values varying more than a thousand-fold. This is the direct result of the calculation method used, combining the single indicators into the resulting Waste Practice Ranking. The multiplication of the different, although not fully independent indicators (e.g. a system with a high score for recycling rate tends to have higher values for diversion from landfilling and environmental impact as well), would not seem to represent the best option. Therefore, as an improved methodology a simple arithmetic mean is proposed. The results of the Waste Practice Ranking calculated according to this method are shown in table 7.

Tab. 7: Indicator scores for the Waste Practice Ranking of four European countries (arithmetic mean calculation method)

Country	Generation	Recycling Rate	Diversion from Land-filling	Environmental Impact	Waste Practice Ranking
Catalonia	0.46	0.18	0.41	0.43	0.37
Germany	0.53	0.53	0.81	1.00	0.72
Netherlands	0.51	0.42	0.89	0.49	0.58
Poland	0.70	0.05	0.09	0.03	0.22

The resulting values for the Waste Practice Ranking reported in table 7 seem to be more realistic. Accordingly, the 'arithmetic mean' calculation method will be investigated in detail in further research studies.

4 Conclusions and Outlook

The evaluation of national waste management systems generally focuses on one specific aspect. This aspect may vary from 'generated amount of waste' to 'environmental impacts' of the waste management system, often determined by use of LCA or other methodologies. Whereas the former fails to consider the fate of the waste generated, the latter does not acknowledge the merits of waste avoidance. To overcome this problem a Waste Practice Ranking is proposed. In this ranking the Generation and Recycling Rate of household waste as well as the rate of Diversion from Landfilling and the Environmental Impact of the waste management systems of the countries investigated are considered. The most logical way of combining these aspects is by means of calculation of the arithmetic mean of their determined indicators.

Within the next year the proposed Waste Management Ranking will be evaluated and applied in all European Union countries. By that time the first publication of statistical data for wastes performed according to the new EU Regulation on Waste Statistics (EP&C, 2002) and scheduled to cover the year 2004 (EC, 2005), should have been made available by Eurostat.

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