Waste Biomass Valor (2010) 1:479–486
DOI 10.1007/s12649-010-9043-5

ORIGINAL PAPER

Indicators for Valorisation of Municipal Solid Waste and Special Waste

Eva Cifrian · Alberto Coz · Javier Viguri · Ana Andrés

Received: 26 February 2010 / Accepted: 15 September 2010 / Published online: 7 October 2010

Abstract Indicators are important tools that assist decision-makers in formulating and implementing plans for the management of waste at local, national and international levels. An indicator is an elementary datum or a simple combination of data capable of measuring an observed phenomenon. Indicators are there to enhance communication about the environment and to serve as a tool for policy-making. Indicators can be used to track progress over time, or to compare characteristics between one or more communities, companies, agencies, departments, products or processes. By examining these indicators over time or between different regions, communities, etc., improvements or setbacks in resource use and waste generation can be identified. In addition, these indicators can be used to illustrate the shift in industrial strategy away from end-of-pipe processes towards waste recycling, cleaner production and integrated lifecycle analysis. Different sets of environmental indicators that convey information about waste valorisation at the regional level have been developed. Indicators of reuse, recycling and other recovery like energetic valorisation related to different kinds of waste are presented. In this paper two groups of indicators are defined; the first one evaluates the valorisation of different components of municipal solid waste: treatment of municipal solid waste, recycling of glass packaging, recycling of paper and cardboard, valorisation of light packaging and energy produced from municipal solid waste. The second one evaluates the valorisation of different kinds of special waste with other kinds of treatments applied to this special waste: treatment of construction and demolition waste, used tyres management, production and disposal of municipal wastewater sewage sludge, and collection and management of waste electrical and electronic equipment. The obtained indicators of the defined methodology are applied to the region of Cantabria (Spain) presenting that the waste management in this region is good. The information of the indicators can serve as a reference for decision-making and implementing useful tools for enhancing the valorisation of waste at the regional level.

Keywords Environmental indicators · Valorisation · Municipal solid waste · Special waste · Waste management

E. Cifrian · A. Coz · J. Viguri · A. Andrés (✉)
Chemical Engineering Department, University of Cantabria, Santander, Spain
e-mail: andresa@unican.es

Introduction

Regional, national and international environmental regulations governing waste management are rapidly increasing in number. Usually, there is an implementation gap between the high-level policy ambitions related to environmental governance in the waste sector (as expressed in national policy frameworks) and local-level decision-making procedures and outcomes [1–4]. All of these policies propose a series of objectives and targets that must be evaluated and observed during implementation of the plans. These regulations also propose a series of actions to help to achieve these goals. It is necessary to closely monitor progress towards these objectives to assess the actions taken and to change the actions in cases where the objectives are not being met [5].

Furthermore, the Convention of Aarhus [6] on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters issued Directive 2003/4/CE [7] on public access to environmental information, which requires that all existing environmental

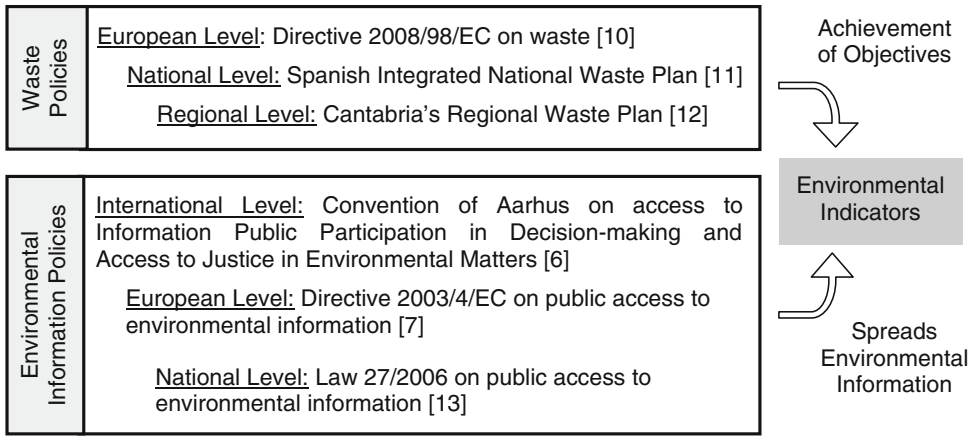


Fig. 1 Need for environmental indicators

information be publicly accessible. Environmental indicators are useful tools for spreading environmental information, reflect trends in the environment and monitor the progress made in realising environmental policy targets [2] (Fig. 1).

Decision-makers are living in a strange paradox: there is both too much and too little information. The vast amounts of information available are not meeting the needs of decision-makers. In addition, problems are perceived as more complex than ever, and more sophisticated tools are needed to feed information into decision-making. Indicators are seen as one solution to bridge this gap [8, 9].

An environmental indicator is a measurement that can be used to illustrate and to communicate a complex phenomenon in a simple way [14], including tendencies and changes through time. They have to fulfil scientific, functional and pragmatic requirements and many criteria as transparency, policy relevance, measurability, or robustness, between others [15]. There are different types of indicators that are useful in the context of supporting environmental policy: descriptive indicators, performance indicators and efficiency indicators [2].

A wide array of environmental indicators has been compiled by different international organizations and countries and many indicators sets are already available [14, 16–21]. They are mostly focused on national or global scale and their approaches and objectives differ substantially at times [22, 23]. International, European and national organization focus their attention on the elaboration and selection of various set of indicators for measuring the actual situation [24]. On a regional level, the problems may be different and need tailored tools. However many regional indicator sets have failed to thrive, due shortcomings in their development process [9].

Indicators are often selected based on historical practices and regulations, or they are based on the "intuitive assessment of experts" [22, 25]. In addition, they are selected based on the degree to which they meet a number of criteria individually rather than on the basis of how they jointly provide an answer to our environmental questions. The scientific basis of the selection process of the indicators used in environmental reporting could be significantly improved. In many studies, no formal selection criteria are mentioned. Often, no formal criteria are applied regarding an analytical utility of indicator within the total constellation of a selected set of indicators. As a result, the indicator selection process is more or less arbitrary [26].

In the region of Cantabria, waste information management is carried out through two sets of indicators with different purpose: basic indicators and specific indicators. In a previous work [3], basic indicators have been used to allow a comparative evaluation of results obtained in different contexts. These indicators allow comparisons between the situation and evolution of waste production and management in Cantabria, and other regions, or whole countries. To obtain answers to more concrete policy questions and to identify priority actions, more detailed indicators are needed, and thus a set of specific indicators has been established [27]. These indicators assess the achievement of the objectives of the Regional Waste Plan which is derived of National and European policies. The indicators related to waste recovery i.e., indicators of reuse, recycling and other recovery like energetic valorisation, are presented in this paper.

Methodology

In order to obtain the sets of indicators, two different methodologies were developed in previous work [3, 27]. A different methodology was necessary for each set of indicators, because each one has different purposes, and its indicators may have different properties. The methodologies for developing sets of indicators consist of four stages: synthesis, development, implementation and interpretation of results. The two methodologies developed differ only in the synthesis of the indicators stage.

First set, basic indicators, was developed with the purpose of allowing a comparative evaluation of results obtained in different contexts. To select the indicators for this set the methodology of Fig. 2 was applied.

To select the indicators for basic set, a complete review of waste indicators used by different organizations, countries, and regions was accomplished. From this review a large list of indicators of waste was obtained, and the indicators more used by these organisms were selected. Then it was necessary to reduce the list of indicators applying other criteria.

A suitable indicator must fulfil criteria as [14, 28, 29]: relevant: related to goals, objectives and priorities; credible: based on complete and precise data; functional: useful in the decision making; quantifiable: measurable with relative facility; and comparable: at spatial and temporal different scale.

The second set, special set, was developed with the purpose to obtain answers to more concrete policy questions and to identify priority actions. These indicators evaluate the achievement of objectives of Waste Plans. The methodology to obtain the special indicators set is showed in Fig. 3 [27]. The policy objectives and targets identified in the waste policies were the starting point for developing a set of indicators on waste. In the synthesis of the indicator, the methodology carry out in the European topic centre on waste and material flows [30] were used. The methodology, get started from specific objectives of waste policies. The local policy objectives are shared out in four groups: prevention objectives, recycling and reusing objectives, incineration objectives and disposal objectives.

To each objective or group of objectives, was necessary to find the policy question that generate it, and the single indicator that answer this policy question. The policy question was essential to give a complete view of the matter. The indicator not only evaluates a specific target, but evaluates a complete matter. These single indicators can be combined, if two or more evaluates different parts of the same matter, to get a key indicator. With key indicators the number of indicators decreases and gives a fast vision of the policy achievement, instead of complicate the analysis with a great amount of data and trends. These three steps establish the indicator synthesis.

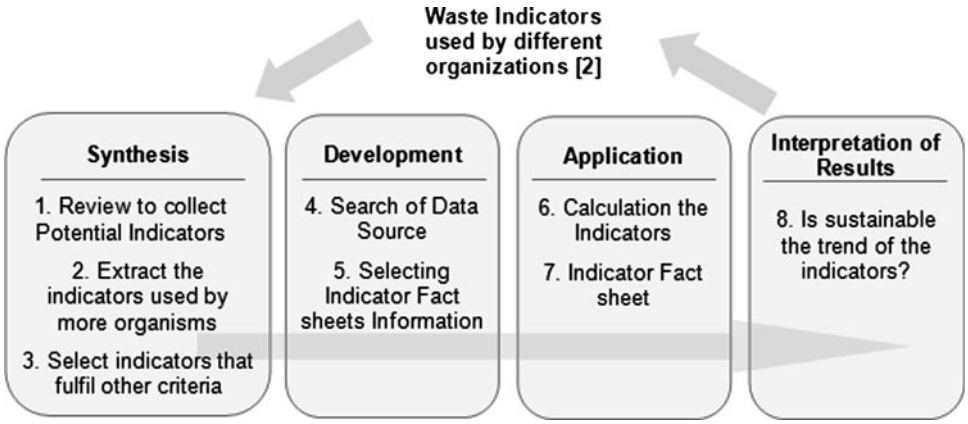


Fig. 2 Methodology for the selection of the basic set indicators

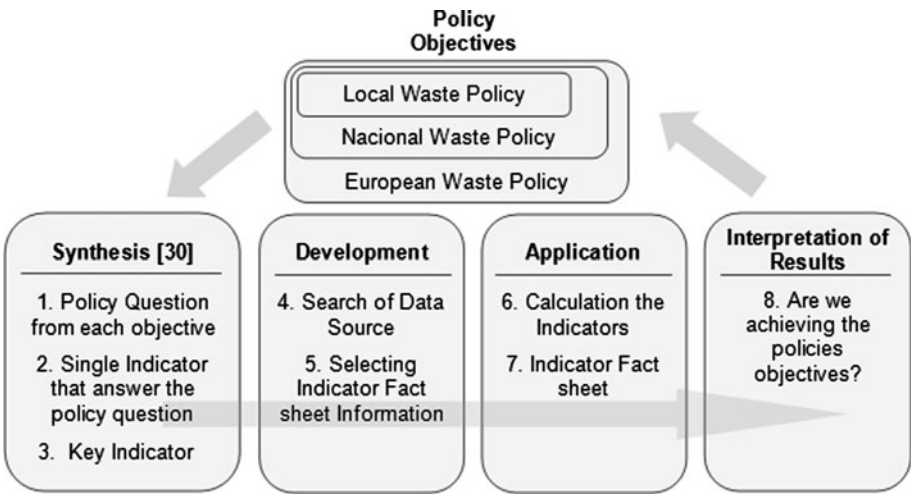


Fig. 3 Methodology for the selection of the specific set indicators

Table 1 Interpretation of results

Icon	Description
	Positive trend. It is possible to get objectives
	Positive trend but it is not possible to get objectives
	Negative trend. It is impossible to get objectives
	Tendency is not evidenced. No data available

Once both sets of indicators were defined, it was necessary to obtain data for their development and selecting the contents for the factsheets of the indicators. These factsheets collect the information required to understand its trend, information about the issue of the indicator, policy objectives, or legislation among others.

The application step was divided in two sections, the calculation of the indicator, and the development of the Factsheet information. The application stage consists of calculating the indicator from data obtained in the previous step and then completing the contents of an indicator factsheet.

Finally, the interpretation of results was different in each set of indicators. In basic set the interpretation consists of answering the following question: Is sustainable the trend of the indicators? This question can be answered comparing the results of the indicators with other regions. In the specific set the question was: Are we achieving the policy objectives? The question can be answered comparing the results with the objectives planned in the policies. The possible answers to these questions are presented in Table 1 [31].

Results and Discussion

The synthesis step of both methodologies were applied and two different sets of indicators were made [3, 27]. The results obtained are two sets of indicators that are grouped according to the different types of management proposed by the European Union [10]: prevention of waste, preparing for reuse, recycling, other recovery like energetic valorisation and disposal. The indicators on which this work is focused are related to waste valorisation (Fig. 4).

The set of indicators obtained is divided into two categories depending on the kind of waste: municipal solid waste or special waste (Table 2).

The second step is the development of the indicator. In order to calculate the value of the indicators, it was

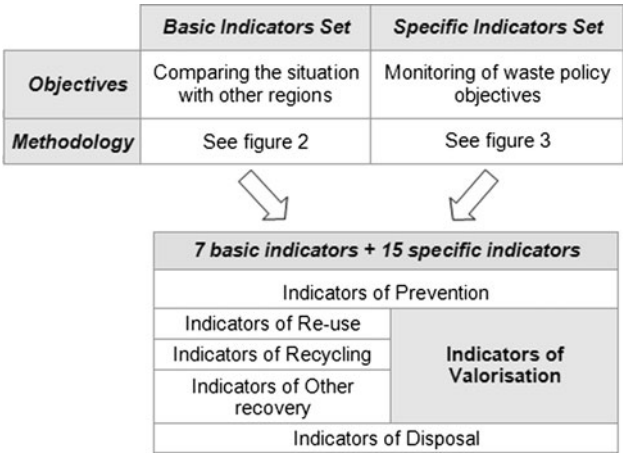


Fig. 4 From indicators sets to indicators of waste valorisation

Table 2 Indicators of waste valorisation

Indicator of municipal solid waste	Indicator of special waste
Treatment of municipal solid waste	Treatment of construction and demolition waste
Recycling of glass packaging	Used tyres management
Recycling of paper and cardboard	Production and destination of municipal wastewater sewage sludge
Valorisation of light packaging	
Energy produced from municipal solid waste	Collection and management of waste electrical and electronic equipment

necessary to obtain data. To search the data source, it is indispensable to define the scope of the indicator and the number and kind of variables and data that are needed.

A. *Treatment of municipal solid waste* This indicator takes into account the percentage of total municipal solid waste managed in each kind of treatment. This consists of four variables: the percentage of waste sent to (i) landfills, (ii) composting, (iii) recycling and (iv) energetic valorisation. Monitoring the quantity of waste sent to each management technology per year helps ensure that the environmental management is according to European policies. Also, monitoring may reduce the waste sent to landfills and incineration (especially without energy recovery) in favour of composting and selective collection, in which materials are reused and recycled.

B. *Recycling of glass packaging* The glass recycling rate is calculated as the ratio between the amount of glass collected for recycling and the amount consumed. The amount of glass collected comes from selective collection in street containers, recycling and composting plants, and selective collection point, and it is equivalent to glass from

households. The amount of glass consumed is equivalent to the quantity of glass packaging that the factories have sold with their products.

C. *Recycling of paper and cardboard* The paper and cardboard recycling rate is calculated as the ratio between the amount of paper and cardboard collected for recycling and the amount consumed. The amount of paper and cardboard collection comes from selective collection in street containers, recycling and composting plants, selective collection points, and door to door collection from shops. The quantity of paper and cardboard collected for recycling takes into account both printed paper and cardboard packaging. The amount of paper and cardboard consumed is equivalent to the quantity of paper and cardboard produced minus the difference between the quantity exported and the quantity imported.

D. *Valorisation of light packaging* The light packaging recycling rate is calculated as the ratio between the amount of light packaging collected for recycling and the amount consumed. The quantity of light packaging collected comes from selective collection in street containers, recycling and composting plants and selective collection points, and the quantity of different packaging material in the selective collection containers and the losses due to the packaging separation process are subtracted.

E. *Energy produced from municipal solid waste* This indicator assesses the strategies implemented in the region by which energy is obtained from municipal solid waste. The indicator is calculated as the quantity of energy produced by biogas from landfills and from incineration of municipal solid waste.

F. *Treatment of construction and demolition waste (C&DW)* This indicator takes into account the quantity of construction and demolition waste sent to each kind of treatment. This indicator consists of three variables: the percentage C&D waste sent to recycling, environmental restoration and landfills.

G. *Used tyres management (UT)* This indicator take into account the quantity of used tyres sent to each kind of treatment. This indicator consists of three variables: the percentage of used tyres sent to recycling and reuse, energetic valorisation and disposal.

H. *Production and disposal of municipal wastewater sewage sludge (MWSS)* This indicator assesses the strategies implemented in the region for the management of municipal wastewater sewage sludge. This indicator consists of three variables: the percentage of MWSS sent to energetic valorisation, landfills, and used in agriculture.

I. *Collection and management of waste electrical and electronic equipment (WEEE)* This indicator assesses the quantity of WEEE collected and the quantity of these wastes sent to reuse, recycling and energetic valorisation.

The number and kind of variables and data that are needed for the development of the special waste indicators is summarized in Table 3.

In order to show the elaborated indicators, an indicator factsheet has been designed [23]. This factsheet presents the evolution over time of the indicator data, as well as another series of information that help to explain why the indicator follows that trend over time and whether it is the wished one. The information selected for the indicator factsheet is summarised in Table 4.

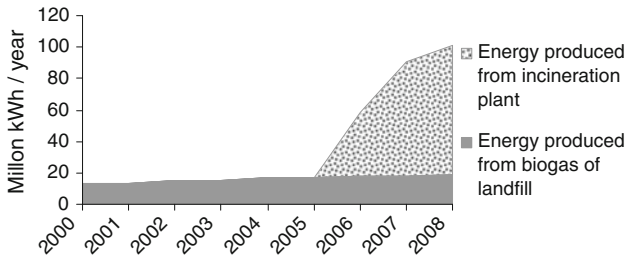
Table 3 Data needed to develop the special indicators

Indicator	Variable	Data
Treatment of construction and demolition waste	C&DW to landfill	Quantity and percentage of C&DW to landfill
	C&DW to recycling	Quantity and percentage of C&DW to recycling
	C&DW to environmental restoration	Quantity and percentage of C&DW to environmental restoration
Collection and management of waste electrical and electronic equipment	Collection of WEEE	Quantity of WEEE collected
	Recycling of WEEE	Quantity and percentage of WEEE recycled
	Energy valorisation of WEEE	Quantity and percentage of WEEE to energy valorisation
Used tyres management	UT to landfill	Quantity and percentage of UT to landfill
	UT to authorized manager	Quantity and percentage of UT to authorized manager
	UT to energy valorisation	Quantity and percentage of UT to energy valorisation
Production and destination of municipal wastewater sewage sludge	Production of SS	Quantity of SS generated
	SS to agriculture	Quantity and percentage of SS to agriculture
	SS to landfill	Quantity and percentage of SS to landfill
	Sewage sludge to energy valorisation	Quantity and percentage of SS to energy valorisation

Table 4 Information of indicators factsheet

Label	Information
Icon	Displays the achievement of the objectives
Description	In this subsection, the main aspects of the waste indicator and the management techniques are explained
Policy objectives	Local or national policy objectives that the indicator can evaluate
Progress over time	Shows graphically, and in some cases with tables, data regarding the temporary evolution of the indicator. The indicator can be composed of a single graph or more. A description with keys that help explain the evolution is included along with the graphs.
Analysis of achieving degree of policy objectives	Analysis of achieving degree of the objectives of Plan that are evaluated by this indicator.
Proposed actions	Proposed actions in the policies that can help to achieve the objectives
Calculation methodology	Necessary formulas for calculating the indicator
Data sources	Explain what are the different organizations that are sources of data for the indicator

Table 5 Factsheet information for the indicator energy produced from municipal solid waste

Information	Energy produced from municipal solid waste
Description	Once the wastes are disposal in the landfill, the decomposition of organic matter in absence of oxygen is produced, giving place a mixture of flammable gases named biogas. This gas is evacuated from the landfill, because if the gas stays in the landfill can cause explosions and fires. As preventive solution are inserted in landfill a network of pipelines that collect the gas and leads to a recovery centre where occurs controlled combustion taking the calorific power of the gas and transforming it into energy. Another way of obtaining energy, which is taking into account in this indicator, is waste incineration. Incineration is a technique preferential to elimination in landfill, because it uses the calorific power of materials, and is limited to treat the fraction of waste that could not be recycled. This technique can reduce 70 and 85% of the volume of waste.
Policy objectives	- Increase the energy recovery from biogas of landfills and the MSW incineration installations.
Progress over time	
Analysis of achieving degree of policy objectives	The energetic valorisation of the biogas that is retrieved from the landfill of MSW of *Meruelo* is implemented yet, and the evolution of energy produced is ascending. The incineration of waste plant has been implemented in 2006 and has begun to work at its rated capacity in 2007.
Proposed actions	- Continue with energetic valorisation of the biogas of landfill. - Energetic valorisation in the incineration plant of the Municipal Solid Waste.
Methodology of calculation	The indicator is calculated as the addition of the quantity of energy produced from biogas of landfill and incineration plant.
Data sources of the indicator	Enterprise responsible of landfill and incineration plant management (MARE).

Next step is the application: calculation the indicator and complete the factsheet; e.g. the calculation of the indicator Energy produced from municipal solid waste consists in the addition of the quantity of energy produced by biogas from landfill and incineration plant. The Factsheet developed for this indicator, with the graphical evolution of the data and other information is summarized in Table 5.

Table 6 Interpretation of results

MSW indicator	Result	Special waste Indicator	Result
Treatment of municipal solid waste		Treatment of construction and demolition waste	
Recycling of glass packaging		Used tyres management	
Recycling of paper and cardboard		Production and destination of municipal wastewater sewage sludge (MWSS)	
Valorisation of light packaging		Collection and management of waste electrical and electronic equipment (WEEE)	
Energy produced from municipal solid waste			

Finally, in the step of interpretation of results, the indicators are compared with the situation of other regions or with the policy objectives. The results obtained are summarized in an icon, which shows the degree of achievement of the indicator (Table 6).

Waste recovery in Cantabria, according to indicators developed, is good. Seven of the indicators have an icon of good tendency: treatment of municipal solid waste, recycling of glass packaging, recycling of paper and cardboard, valorisation of light packaging, energy produced from municipal solid waste, used tyres management and production and destination of municipal wastewater sewage sludge, but with three of them, it is not enough to achieve the objectives. Two of the indicators, treatment of construction and demolition waste and collection and management of waste electrical and electronic equipment, have a bad tendency.

Conclusions

In order to evaluate the waste management activities planning in the region of Cantabria and to spread all the information related to waste, a set of indicators has been developed. On the one hand, these indicators assess the achievement of a series of objectives and targets purposed in regional and national waste plans, and on the other hand, summarize all the information of the regional waste production and management and make this information publicly accessible.

The methodologies for developing sets of indicators consist of four stages: (i) synthesis of the indicators set, (ii) development, obtaining data and selecting the contents for the factsheets, (iii) implementation, calculation the indicator, and development of the factsheet and (iv) interpretation of the results.

The indicators, on which this work is focused, are related to waste valorisation, that is to say, they are indicators of reuse, recycling and other recovery like energetic valorisation. The result obtained is a set with the following indicators: treatment of municipal solid waste, recycling of glass packaging, recycling of paper and cardboard, valorisation of light packaging, energy produced from municipal solid waste, treatment of construction and demolition waste, used tyres management, production and destination of municipal wastewater sewage sludge and collection and management of waste electrical and electronic equipment. Each indicator has a factsheet with information like, the policy objectives that this indicator assesses, the progress over time, or the actions proposed in the Waste Plan to achieve the objectives, among others. Furthermore, an icon is attached to each indicator like a summary of its progress. This icon represents the result obtained of comparing the evolution of the indicator with the planned target.

Waste recovery in Cantabria, according to indicators developed, is good. Seven of the indicators have an icon of good tendency and only two, treatment of construction and demolition waste and collection and management of waste electrical and electronic equipment, have a bad tendency.

The methodology developed and applied is a good tool for the evaluation of waste management activities at Cantabria regional level, and would be useful to be applied in other regions. The set of indicators developed is useful too to measure the improvements in the management aspects that have shown a bad tendency.

Acknowledgments This work has been supported by a R+D+I project entitled "Sistema de Indicadores para el Flujo Sostenible de Recursos y Residuos. Punto Focal de Residuos de Cantabria" between the Cantabrian Government and University of Cantabria, Spain. E. Cifrian was funded by the University of Cantabria by means of a predoctoral fellowship.

References

1. European Environment Agency: Environmental indicators: typology and use in reporting. EEA internal working paper (2003)
2. European Environment Agency: Assessment of information related to waste and materials flows, EEA Technical Report No. 96. ISBN: 92-9167-577-6 (2003)
3. Cifrian, E., Arce, R., Andrés, A., Coz, A., Muñoz, Y., Viguri, J.: Set of indicators on waste needed to support environmental information management. Chemistry and Sustainable Development- Abstracts Book 2. ISBN 84-690-2349-7 (2006)
4. Sikdar, S.K.: Sustainable development and sustainability metrics. AIChE J **49**(8), 1928–1933 (2003)
5. Nilsson, M., Eklund, M., Tyskeng, S.: Environmental integration and policy implementation: competing governance modes in waste management decision making. Environ. Plan. C Gov. Policy. **27**(1), 1–18 (2009)
6. UNECE: Convention on access to information, public participation in decision-making and access to justice in environmental matters. Done at Aarhus, Denmark, on 25 June 1998
7. European Commision: Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC (Official Journal L 41, 14.2.2003, p.26)
8. Atkinson, G., Hamilton, K.: Accounting for progress: Indicators for sustainable development. Environment. **38**(7), 16–20 (1996)
9. Mickwitz, P., Melanen, M., Rosenström, U., Seppälä, J.: Regional eco-eficiency indicators–a participatory approach. J of Clean. Production **14**, 1603–1611 (2006)
10. European Commission: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Official Journal L 312, 22.11.2008, p. 3)
11. Gobierno de España: Resolución de 20 de enero de 2009, de la Secretaría de Estado de Cambio Climático, por la que se publica el Acuerdo del Consejo de Ministros por el que se aprueba el Plan Nacional Integrado de Residuos para el período 2008-2015. (BOE 49, 26.02.2009, Sec.I p. 19893)
12. Gobierno de Cantabria: Decreto 102/2006, de 13 de octubre, por el que se aprueba el Plan de Residuos de Cantabria 2006-2010. (BOC 245, 26.12.2006, p. 15315)
13. Gobierno de España: Ley 27/2006, de 18 de julio, por la que se regulan los derechos de acceso a la información, de participación pública y de acceso a la justicia en materia de medio ambiente (incorpora las Directivas 2003/4/CE y 2003/35/CE). (BOE 171, 19.07.2006, p. 27109)
14. European Environmental Agency: EEA core set of indicators, guide. EEA Technical report/No1, ISSN 1725-2237 (2005)
15. Jesinghaus, J.: Indicators for decision-making. European Commision, JRC/ISIS/MIA, TP 361, I-21020 Ispra (VA) (1997)
16. European Environmental Agency: Catalogue of forward-looking indicators from selected sources: A contribution to the forward-looking component of a shared environmental information system (SEIS/Forward). EEA Technical Report No. 8. ISSN 1725–2237 (2008)
17. Eurostat: Measuring progress towards a more sustainable Europe - 2007 monitoring report of the EU sustainable development strategy. Luxembourg: Office for Official Publications of the European Communities. ISBN 978-92-79-05043-5 (2007)
18. Ministerio de Medio Ambiente Español: Banco Público de Indicadores Ambientales. http://www.mma.es/portal/secciones/calidad_contaminacion/indicadores_ambientales/banco_publico_ia/#4. Accessed 15 December 2009
19. OECD (Organisation of Economic Co-operation and Development): OECD environmental indicators: Development, measurement and use. Reference Paper (2003)
20. Observatorio de la Sostenibilidad en España. Sostenibilidad en España 2008.http://www.sostenibilidad-es.org/NR/rdonlyres/665F21EB-BE50-47B1-ACBC-B68C9DBDDD60/0/INFORME_08_BAJA_RESOLUCION2.pdf. Accessed 18 January 2010
21. Rosenström, U., Lyytimäki, J.: The role of indicators in improving timeliness of international environmental reports. Eur. Env. **16**, 32–44 (2006)
22. Donnelly, A., Jones, M., O'Mahony, T., Byrne, G.: Selecting environmental indicator for use in strategic environmental assessment. Environ. Impact Assess. Rev. **27**(2), 161–175 (2007)
23. Punto focal de residuos de Cantabria (In Eng: Focal Point of Residues of Cantabria). http://pfr.medioambientecantabria.com/ (2010). Accessed 10 February 2010
24. Federico, G., Rizzo, G.: Traverso, M: In itinere strategic environmental assessment of an integrated provincial waste system. Waste Manag Res **27**, 390–398 (2009)
25. Bosel, H.: Assessing viability and sustainability: a system-based approach for deriving comprehensive indicator sets. Conserv. Ecol. 5, 12 (2008)
26. Niemeijer, D., Groot, R.: A conceptual framework for selecting environmental indicator sets. Ecol. Indic. **8**, 14–25 (2008)
27. Cifrian, E., Álvarez, M., Viguri, J., Andrés, A.: Environmental management strategies: developing a set of indicators as a decision-making support in waste policy. In: 8th World Congress of Chemical Engineering. Book of Abstracts. ISBN 0-920804-44-6 (2009)
28. OECD: OECD Environmental indicators: Towards Sustainable Development. Organisation for Economic Cooperation and Development, Paris, 45 pp (2001)
29. Kurtz, J.C., Jackson, L.E., Fisher, W.S.: Strategies for evaluating indicators based on guidelines from the Environmental Protection Agency's Office of Research and Development. Ecol. Indic. **1**, 49–60 (2001)
30. European Topic Centre on Waste and Material Flows: Towards a core set of indicators on waste and material flows. European Environmental Agency, 32pp (2002)
31. European Environmental Agency: Environmental Signals 2002. Benchmarking the millennium. EEA Environmental Assessment Report No 9 (2002) 14–25