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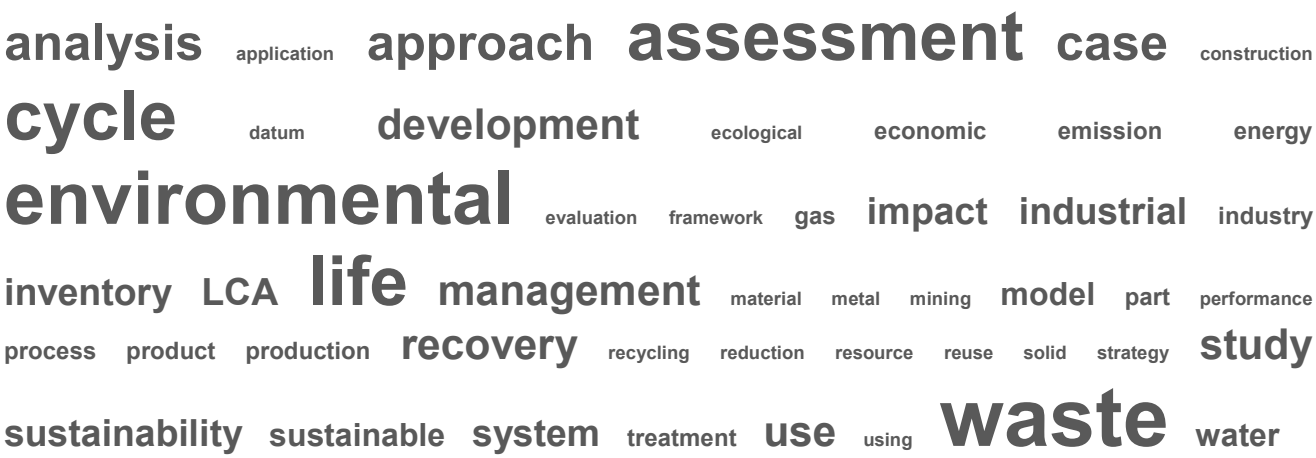

A review of social science in five industrial ecology journals

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Cover:
Word cloud for the titles of the 200 articles sampled in this study. The articles were randomly sampled from all abstracted articles identified to have been published in the journals International Journal of Life Cycle Assessment, Journal of Industrial Ecology, Journal of Cleaner Production, Progress in Industrial Ecology and Resources, Conservation & Recycling from the first issues of these journals and until and including 2010. Word cloud created using WordSift, by Stanford University, at http://www.wordsift.com/, on 2 July 2014.

Chalmers reproservice
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SUMMARY

A major aim in the industrial ecology (IE) field is to reduce environmental burdens through industrial change. In order to aid and to reflect on this aim, scholars in the field have repeatedly called for or presented opportunities for research on the social aspects of IE, such as organisation cultures, legislation and environmental policy. However, the study of 'social IE' has remained fragmentary. In this study, an understanding for this discrepancy between calls and a marginal progress is systematically searched for. Five journals in the field are reviewed – Journal of Industrial Ecology; Progress in Industrial Ecology; the International Journal of Life Cycle Assessment; Journal of Cleaner Production; Resources, Conservation and Recycling – covering the years 1988-2010 and backed up by a continued reading of their table of contents into the year 2014. Both 'social IE' studies and IE studies in general are covered. An empirically based approach is used, resulting in the following findings. The number of articles published has been growing rapidly since the first of the journals was launched, in 1988. JCP and PIE have the highest shares of 'social' articles within each of the journals. A large number of the studies, 49%, cover social aspects, whereof economic aspects account for a large part. For both the studies on social aspects in general and on economic aspects, the absolute number of articles has increased over the years while their shares of the field have remained stable. Analysing the whole field, the articles often seem to be user oriented which importantly includes that they to a relatively little extent make explicit use of or are explicitly designed to be compared to other studies. Also, when looking closer at the 'social' articles, it is revealed that only a small part of the 'social' aspects are researched using social science theory, and then often using marginally established theories. In addition, no or very few of the 'social IE' studies align to any of the paradigms that represent a large part of the social sciences during the last half century. Finally, from a survey of proxies of 'social IE' sub fields, four rather small groupings are identified: life cycle costs, life cycle management, supply chain management with several associated concepts, and social life cycle assessment. Reflections on the limitations of this study and on the findings as such point to possible needs for more holistic and society-wide approaches to understanding the research problem identified in this study.

Keywords: industrial ecology, social science, social aspects, economy, review, empirically based study, material and energy flows, journals, LCC, LCM, SCM, SLCA

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1. Introduction

A central aim in the industrial ecology (IE) field is to provide knowledge about how industrial change may help reducing environmental burdens (cf JIE 2010). In order to aid and to reflect on this aim, scholars in the field have over the years called for or presented opportunities for social science perspectives on IE. Already in the early 1990s, Bruce Piasecki (1992) proclaimed that IE was a management science. The launch of the journal Progress in Industrial Ecology (PIE), in 2004, was an attempt in the same direction, by encouraging scholars to bridge IE to business, management and organisational studies (Korhonen & Strachan 2004). More recently, in 2009, the anthology "The social embeddedness of industrial ecology" was published with the aim of informing industrial ecologists about "the social science perspective" (Boons & Grenville-Howard 2009:xvi). Since the issue of **'social IE'** research is repeatedly brought forward, there seems to be both a need for and an interest in it.

However, nearly two decades have passed between the publishing of Piasecki's article and the release of The social embeddedness of industrial ecology. Compared to the broadness of this anthology's title this hints to a slow progress of actual 'social IE' studies.

This far, a few starting points exist for understanding this discrepancy. One representative point comes from a personal reflection on cultural differences between engineers and social scientists (see Baumann 2009). Another is based on a description of the limited understanding of environmental issues in one field that IE has been trying to reach towards: corporate environmental management (CEM) (also called organizations and natural environment-related research) (Kallio & Nordberg 2006; on the relevance of this field to IE see Korhonen & Strachan 2004). These texts only provide tentative explanations, but, nevertheless, the publication of such perspectives and the insights they provide make further analysis of 'social IE' research seem both relevant and feasible.

Therefore, this study aims to broaden and deepen the understanding of this discrepancy between the calls for and actual development of 'social IE' research. In order to handle the large scope of the IE field the study is performed as a literature review. Further, to cover this little and fragmentarily studied issue, the review is designed as a systematic exploration.

In the next chapter, the scope of the IE field and the to the study central scope of the term 'social' are discussed. Also, the previous research found on the topic of this study is outlined in more detail. This is followed by a description of the research design of this study, where the focus lies on showing how the path towards the aim of this project is attempted to be reached via a study of journal

articles. Specifically, the covering of both ‘social IE’ studies and of IE studies in general is explained. In the subsequent chapter, a quantitative presentation is made of raw data from the results. This is followed by complementary comparisons of and descriptions of a selection of seemingly particularly relevant results. Finally, limitations and opportunities of this study are discussed, and they are presented together with a summary of the findings from the previous chapters.

2. Points of departure

2.1. Industrial ecology as a field

The methodological platform of studies on material and energy flows related to environmental impacts, and to these flows closely related aspects such as their management, share similar borders to research usually gathered under the term IE (cf JIE 2010). This both shows that IE is in practice a research field and that the term's methodological consistency makes its at least moderately clear boundary useful as a delimitation criterion for for example review studies.

The research field of IE is also internationally established through journals, a society, and conferences. Two journals explicitly carries its name – Journal of Industrial Ecology (JIE), published since 1997, and the already in the Introduction chapter mentioned Progress in Industrial Ecology (PIE), launched in 2004. As a complement, the International Society for Industrial Ecology (ISIE) has been promoting IE since 2001 and is associated to JIE (ISIE 2012). Finally, two biannual conferences exist, one organised by the Gordon Research Conferences since 1998, and the ISIE Conferences, held since 2001.

2.2. 'Social' aspects

In this section, the use of the term 'social' in this report is elaborated upon.

The use of the term 'social' in this report is closely related to the scope of the report. Due to the seeming interest in and difficulty of progressing research on aspects of IE that lie outside of the engineering and natural sciences, it is useful to denote all of these aspects using one term. We have in this report chosen to use the term 'social' for this labelling since it is often used for covering this wide range of issues in the broad use of the term social science(s) (cf OED Online 2012b).

Therefore, 'social' coverage in this study includes human societal, group, and individual aspects including psychology, as well as phenomena that are usually associated with human use and values, such as economy and management systems.

However, this should be noted to be more encompassing than the also common, more narrow use of the concept social science(s), as well as both more narrow and more wide than the use of the term 'social' in everyday language and in dictionary definitions. For example, the common in use definitions of 'social' listed by Oxford English Dictionary cover: the ability of persons and places to facilitate interaction between persons through talking and meeting; high society; referring to many or all persons in a society; and relationships or groupings among humans, animals and plants, respectively (OED Online 2010a).

2.3. Previous studies

The existing points of departure for studying the discrepancy between the calls for and the progress of 'social IE' studies basically come from three studies. The findings from these studies that have been found relevant to this project are outlined in the following.

The first identified starting point is a possible difference in the importance that is put on the environmental aspects between IE and the social sciences that IE has been attempted to be bridged towards. In IE, environmental issues are at least moderately in focus through environmental or flows assessments such as life cycle assessment (LCA) and material flow analysis (MFA) (cf JIE 2010). On the contrary, the social science field CEM, which the PIE journal's editors specifically mentioned as an area that IE ought to be further bridged towards (Korhonen & Strachan 2004), has been shown to be less 'environmental' than its name might indicate. In a literature review on the maturity of CEM studies, Kallio and Nordberg (2006) pointed out that its scholars only to a small extent consider the natural environment.

Further, a comment by Fredrick H Buttel that a similar lack of incorporation of environmental values exists in environmental sociology points to a more general difference in this aspect between IE and the social sciences (cited in Kallio & Nordberg 2006:450). This might partly explain the little bridging this far between IE and these fields.

In addition, environmental sociology is more developed than O&E studies when it comes to internal criticism and developing theories according to Kallio and Nordberg (2006). This indicates that internal criticism in and maturity of a field, whose parent discipline is management science or sociology, not necessarily is a sufficient condition for fostering actual integration of environmental concerns into it.

The second starting point originates in an essay based on personal experiences of interdisciplinary research. Baumann (2009) describes some differences in practices between scholars in IE and in the social sciences. She makes sure that the reader understands that her descriptions are "bordering to stereotype caricatures" (Baumann 2009:55), and then pictures engineers as being motivated by the joy of solving urgent, sometimes environmental, problems while not being particularly focused on evaluating research quality. Contrary, the heterogeneous social scientists are described in her text as having plenty of respect for their study objects as well as for engineers' knowledge.

Some opportunities for integrating IE research with social science are put forward by Baumann (2009) – using philosophy of science to create a mutual understanding, publishing to all kinds of scholars, and being inspired by the satisfaction that researchers have felt when performing interdisciplinary research.

In the already mentioned essay by Baumann (2009), the engineers are characterised both as being creative and as not focussing on critical evaluation. It is not difficult to

see how this creativity could foster calls for furthering ‘social IE’ research. However, the creativity seems to come together with less focus on critical evaluation.

Similar to this, CEM studies is a field where self-reflection is not common, according to Kallio and Nordberg (2006). They explain this phenomenon by the still young age of their field.

Not focussing on critical evaluation may lead to the acceptance of more calls for novel research endeavours such as integrating different research fields. At the same time, this freedom could make the attempts too often fail if the new research trajectories are not enough scrutinised to reach a level of quality that leads to a continuation of or from them.

In addition, Ehrenfeld has reflected upon the prerequisites for a mutual interdisciplinarity between IE and the social sciences. Based on a reasoning made by Habermas, he argues that agreements and consensus are necessary as prerequisites. “Shotgun marriages” are, on the other hand, claimed to be futile. (Ehrenfeld 2009:259-260)

Ehrenfeld (2009) does not elaborate further on forced calls for integration, but from this point of departure the research problem identified in this study, of a discrepancy between the calls for and little development of ‘social IE’ research, could make sense. The more solely the calls are focused on novelty, the less likely that they are based on the at least to some extent novelty harvesting process of agreements and consensus creation.

Summing the above described points from previous research up, published arguments are found on difficulties in, motivating factors for as well as dangers of bridging IE studies to the social sciences. Due to this interest in the issue and since it has been little or mostly from social science perspectives studied this far, we find it relevant to give a descriptive account of the anatomy of ‘social IE’ research and to search for a mapping of IE research in general.

3. Research design

In this chapter, the research design of this study is presented. First, the initial literature searches that led to the scope chosen for the project are presented. The research questions thereby formulated are then outlined. In the following section, the choice of the study objects – journal articles – is elaborated upon, since it has guided the choice of methodology for the study. Therefore, the reasons behind choosing them as well as the selection procedure are described after the research questions. Subsequently, the detailed research design that has been used for the study is being motivated, as well as the further analysis of the results obtained from applying the research design. Finally, the practical tools utilised here, such as databases with search functionality, are presented.

3.1. The path towards the study design

This study emanated from a desire to review how organisational aspects are studied in IE. To get an overview and a starting point for such a study, keyword searches were performed in abstracts, titles and keyword sections of journal articles from journals associated with IE, and using the research database Scopus for the practical carrying out of this.

Through an iterative search process both a large number of search terms were identified as well as a large number of articles retrieved when applying all these terms in the same search. Search terms included for example “chain management”, “organiza*” and “management science”, and eventually the key term list resulted in 1,435 articles matching at least one of them, making up a substantial share of the approximately 5,000 articles that they were delimited from.

A couple of characteristics are particularly notable about these 1,435 articles regarding a review of research on organisational aspects. A large number of these articles were found to cover organisational aspects. Also, many other social aspects, including economic ones, were identified, often together with organisational ones in articles. However, whether an article covered organisational and/or other social aspects was in a substantial share of the articles found not to be quickly and easily determined from for example searching their abstracts for certain keywords.

The large number of organisational and social aspects studies and the difficulty in delimiting them and rather often in even identifying them, led us to mapping not only ‘social IE’ research but also, as mentioned in the last part of the previous chapter, the IE field at large. The study design to handle such a mapping is reasoned about and presented in the following.

3.2. Research questions

Characteristics of the whole IE field have, as reasoned about above, been indicated to be of relevance for understanding the ‘social IE’ research. The previous research

presented in the above chapter also points in this direction. For example, it highlights the (potentially) little presence of research evaluation both in the IE field and in related social science fields (see Baumann 2009, Kallio & Nordberg 2006).

Also, the general IE research reviews of relevance for this study that have been performed as far as we are informed are focussed on more specific issues. One of these reviews is a general mapping of research on environmental product development (see Baumann et al. 2002). The other one points out some themes relevant for how social aspects are defined in IE, such as articles related to history and time and articles having parallels to the environmental management field (Brunklaus 2010).

To cover this here potentially relevant and little studied subject, 'social IE' studies have been complemented in this study by also reviewing IE studies in general.

In addition, before mapping in more detail the 'social IE' research, an overview of the amount of such studies that are performed in the field seemed useful to provide.

The research questions described above, are thus:

1. How is the field industrial ecology constituted?
2. Regarding 'social' aspects research in industrial ecology:
2.a. How large share of the industrial ecology research is on 'social' aspects?
2.b. How are the 'social' aspects studied?

3.3. Study objects

In this section, the delimitations of the study objects reviewed are presented. The selection of a certain publication type of texts, journal articles, is first elaborated upon. This is followed by an argumentation for narrowing this down to the articles in five specific journals. Publication years considered is then shortly reflected upon. Larger delimitations are then given by us choosing to study primarily abstracts from a random sample, and to study proxy areas of and concepts in 'social IE' research.

These delimitations are coupled by the research questions presented in the previous section (3.2.), and are graphically presented and related to these questions in the last part of this section, in Figure 1.

Journal articles

For several reasons, the study objects of this review have been delimited to journal articles. Journal articles are considered to be the most prominent publication form in particularly many of the natural and engineering sciences. Therefore, studies that have been published in journals have been recognised by a broader scientific audience than might be the case for for example publications in report series of research departments.

At the same time, a substantial part of the research in IE could be assumed to be published in journals. Already the two journals carrying the field's name, JIE and PIE, have published 826 articles from the launch of the first of them in 1997 until and including 2010. This could be compared to the limited possibilities in a textbook to cover a large share of the perspectives in a field and in depth describe the contents.

Selection of journals

The selection of which journals to review has been based on two main criteria. The delimitation of IE as environmentally oriented material and energy flows studies discussed in section 2.1. has been used. Citation patterns add further information about the relations between potentially relevant journals and their relations to other journals.

The journals included are the previously mentioned JIE and PIE, as well as the International Journal of Life Cycle Assessment (IJLCA), Journal of Cleaner Production (JCP), and Resources, Conservation and Recycling (RCR).

The similarity between the IE delimitation used in this study and the five journals' contents becomes clear from looking at their aims and scopes (see IJLCA 2011, JCP 2010, JIE 2010, PIE 2011, RCR 2010). In their officially stated aims, all five journals describe a focus on contributing to decreased environmental impacts from human activities. The actor most focused on in these journals' aims descriptions is industry, but all of them also include academia, governments and society to a large extent both as research objects and as target audiences. Material and energy flows are especially central for IJLCA, JIE and PIE but also important in JCP and RCR.

This is supported by the citing patterns that the scientific database Scopus provides, presented in Table 1. Other journals that have cited and that have been cited by these five journals do not have the same core focuses. Also, they are in most cases considerably fewer times citing or being cited by the five journals.

From the citations overview in Table 1, the taken together high number of citations between the five journals is seen. Particularly, IJLCA, JCP and JIE seem from these figures to be closely related to each other. Also, some journals not covered in this study are, based on these figures, many times citing and being cited by all of or by a majority of the five journals: Ecological Economics, Energy Policy, and Environmental Science and Technology (ES&T).

Regarding these three journals not covered in this study, ES&T could be used as an example of the difference in core focus from the five journals reviewed in this study. ES&T covers "a wide range of environmental disciplines." (ES&T 2012) Thereby, ES&T does not have the material and energy flows or the industry focus central to the conception of IE here utilised.

Some caution should however be paid to the figures that this paragraph is based on since several conditions affect the number of citations from and to articles. These are, for example, the amount of articles published by each journal, and the lack of visibility of multiple citations from and to a certain article in the procedure here used to retrieve citation patterns from Scopus.

Table 1: Journal citations of and by the reviewed journals until and including 2010, according to Scopus as of 29 Aug 2011

International Journal of Life Cycle Assessment (1,020 IJLCA articles; 2,908 texts cite IJLCA; 14,117 texts are cited by IJLCA)				
Rank	Articles citing IJLCA		Articles cited by IJLCA	
	Publication	Number of articles	Publication	Number of articles
1	IJLCA	596	IJLCA	626
2	JCP	184	JCP	144
3	Environmental Science & Technology	134	Environmental Science & Technology	131
4	JIE	123	JIE	102
5	RCR	72	RCR	65
6	Energy Policy	40	Chemosphere	51
7	Waste Management	39	Ecological Economics	50
8	Ecological Economics	38	Environmental Toxicology and Chemistry	40
9	Science of the Total Environment	34	Energy Policy	38
10	Renewable & Sustainable Energy Reviews	26	Science	38
>10	PIE*	6	PIE**	1
Journal of Cleaner Production (1,761 JCP articles; 7,570 texts cite JCP; 38,646 texts are cited by JCP)				
	Articles citing JCP		Articles cited by JCP	
1	JCP	752	JCP	1,019
2	IJLCA	227	IJLCA	282
3	RCR	165	Ecological Economics	248
4	JIE	141	Energy Policy	204
5	Energy Policy	116	JIE	188
6	Environmental Science & Technology	110	Business Strategy and the Environment	168
7	Ecological Economics	91	RCR	162
8	Journal of Hazardous Materials	79	Environmental Science & Technology	158
9	Waste Management	79	Computers & Chemical Engineering	127
10	Journal of Environmental Management	76	Energy	118
>10	PIE*	62	PIE**	18
Journal of Industrial Ecology (690 JIE articles; 3,805 texts cite JIE; 17,393 texts are cited by JIE)				
	Articles citing JIE		Articles cited by JIE	
1	JIE	452	JIE	567
2	JCP	186	IJLCA	218

3	Ecological Economics	161	Ecological Economics	205
4	IJLCA	161	JCP	153
5	Environmental Science & Technology	155	Environmental Science & Technology	151
6	RCR	92	Energy Policy	128
7	Energy Policy	69	Science	107
8	PIE*	51	RCR	105
9	Business Strategy and the Environment	48	Energy	63
10	Journal of Environmental Management	41	Nature	59
>10			PIE**	12

Progress in Industrial Ecology*
(122 PIE articles; 87 texts cite PIE;
4,187 texts are cited by PIE)

	Articles citing PIE		Articles cited by PIE	
1	PIE	14	JCP	112
2	JIE	6	JIE	88
3	Ecological Economics	5	Ecological Economics	71
4	Sustainable Development	5	Business Strategy and the Environment	56
5	Geographical Journal	4	PIE	39
6	Environmental Science & Technology	3	Academy of Management Review	34
7	JCP	3	Energy Policy	27
8	Corporate Social Responsibility and Environmental Management	2	RCR	27
9	Energy Policy	2	European Journal of Operational Research	26
10	Journal of Economic Behavior & Organization	2	Journal of Business Ethics	20
>10	RCR	1	IJLCA	9
>10	IJLCA	0		

Resources, Conservation & Recycling
(1,549 RCR articles; 9,282 texts cite RCR;
28,730 texts are cited by RCR)

	Articles citing RCR		Articles cited by RCR	
1	RCR	556	RCR	593
2	Waste Management	390	Waste Management	302
3	Journal of Hazardous Materials	369	JCP	232
4	Bioresource Technology	199	Bioresource Technology	189
5	JCP	141	Water Science & Technology	186
6	Waste Management & Research	139	Waste Management & Research	178
7	Environmental Science & Technology	126	Cement and Concrete Research	169
8	Journal of Environmental Management	90	Environmental Science & Technology	162
9	Industrial & Engineering Chemistry Research	87	Water Research	149

10	IJLCA	80	Ecological Economics	128
>10	JIE	76	IJLCA	108
>10	PIE*	12	JIE	98
>10			PIE**	8

* Covers only the PIE publication years 2006-2010, due to incomplete indexing in Scopus
** Covers the PIE publication years 2004-2010

Years covered

In order to cover all the years during which 'social IE' research has been an issue, all completed volumes of the journals, at the time of data collection for this study, have been included. This dates back to 1988 – for RCR – and includes articles up and until 2010. This is backed up by a reading of tables of contents from these journals into the year 2014.

Use of abstracts

Only abstracted articles have been included in this review in order to use the abstracts to more easily study a large number of articles at a moderate level of depth.

One necessary prerequisite for such an abstract-depending study design is that the abstracts give thorough enough pictures of the corresponding full-texts. This was at an early stage of the process studied through screenings and found to be fulfilled.

Also, it is feasible since most of the articles in the journals are abstracted. The share of articles that are not abstracted until and including 2010 is lower than 1/3 of the total number of articles published for each of the five journals, and not above 5% for PIE, JCP and RCR.

Further, most non-abstracted articles are considerably shorter than the abstracted ones. Therefore, they can be assumed to represent less time put into the research behind and the writing of each of them. Thus, the abstracted articles seem to represent most of the research efforts put into the journals.

Sampling

An overarching further specification of how to study 'social IE' research is prompted by the heterogeneity of these studies. The mentioned broad character of the discussions on the issue points to a not held together research area (see Boons & Grenville-Howard 2009, Korhonen & Strachan 2004, Piasecki 1992). This conclusion is supported by the repeating of calls for or presentations of opportunities of researching the topic further.

Therefore, the 'social IE' part of this study is divided into two sub parts: one broad exploration and one more focused description. The broad exploration is motivated by the possible difficulty to generalise from a small part of the 'social IE' studies. This could for example be the case for the above identified potentially relevant aspect of the level of critical research evaluation in the reviewed studies. A focussed study could, on the other hand, be useful for outlining more specific 'social IE' sub areas or

proxies of such. These areas might be small, and thereby possibly easily overlooked in a broad exploration, and might at the same time indicate how potential maturity of 'social IE' research has developed.

In order to explore general features of IE research and of 'social IE' studies (research questions 1. and 2., respectively), a random sample of articles has been used. The approach of random sampling was chosen because of the little previous research, as described above, and because of the already mentioned heterogeneity of at least 'social IE' studies.

A random selection of a suitable size is assumed to aid the understanding of the 'average article'. This average is also made up of the heterogeneity that a random sample at the same time aid in covering even when they only form a smaller share of the field.

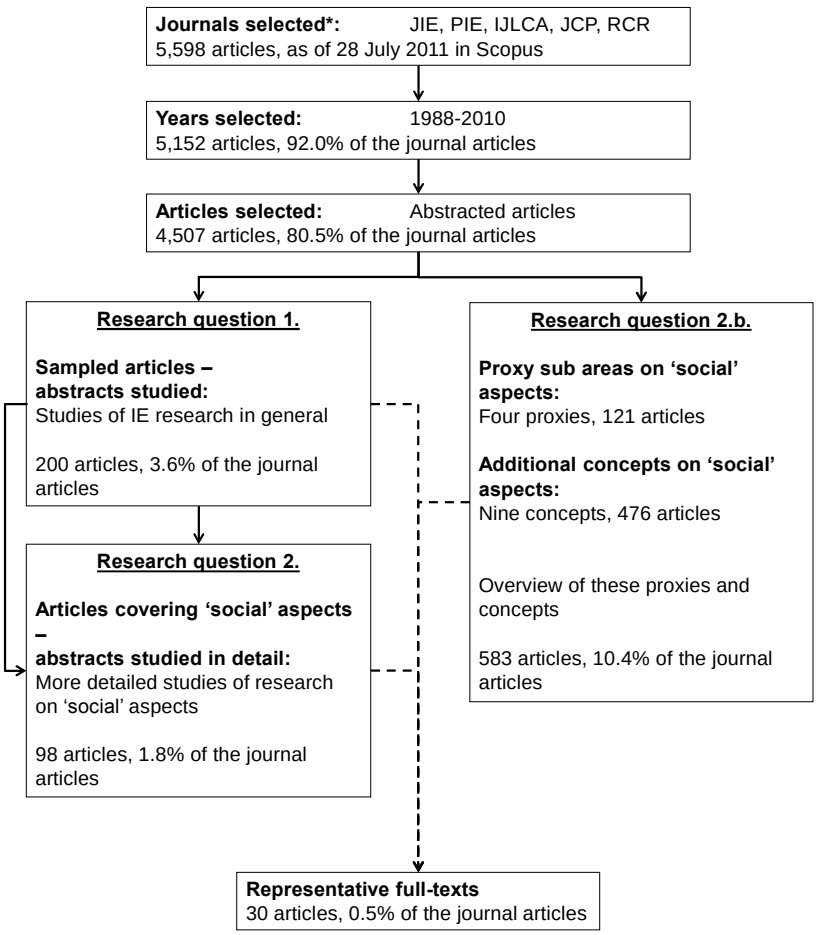
Thus, a sample of 200 articles was chosen. All of their 200 abstracts were studied regarding general IE research characteristics. In addition, those of them found to be covering social aspects – 98 articles – were further analysed regarding these aspects.

The abstract studies were complemented by full-text studies. Thereby, a further verification of the relevance of the abstract studies could be obtained. Also, a more detailed account could be created of the characteristics found in the abstracts.

Identified proxies of sub fields and concepts, on 'social' aspects

In addition to the random sample, in the reviewed articles 24 different and more widely used concepts on social aspects were identified and studied. Out of these 24 concepts, thirteen were found to be more central to the IE field and in total 583 articles out of the reviewed ones were found to cover them. Further, four of the concepts were particularly widely used for methodological and conceptual purposes and have therefore been treated as proxies for sub areas on 'social IE' research in this study. A further description of the selection and handling processes of these 24 concepts is provided under the last sub heading in section 3.6.

Summary of the delimitations of the study objects



*
JIE = Journal of Industrial Ecology
PIE = Progress in Industrial Ecology
IJLCA = International Journal of Life Ccycle Assessment
JCP = Journal of Cleaner Production
RCR = Resources, Conservation & Recycling

Figure 1: The selection process with references to the parts of the research design and with specification of the number of articles studied

3.4. Methods

In this section both the overarching methods of the study and the specific methods used are outlined. An empirically based approach has been used as the guiding method together with the more detail oriented approaches of categorising the article contents together with discourse analysis (DA), and being complemented by identifying proxy sub fields and concepts on 'social IE' research.

Empirically based approach

The guiding criteria for the choice of method have been to reach sufficient width and depth in the exploration of the articles, and moderateness regarding the size of this study. In line with this framing of the study as focused on exploration and basing the scope on the study objects, the rest of the general study approach has also been designed as empirically based. For that purpose it draws on inspiration from the empirically based approach grounded theory (see Glaser & Strauss 2006).

The empirically based approach has its counterpart in using predefined hypotheses to fit data into. In line with this, no discrimination regarding tools and methods for carrying out this study have initially been applied. Also, one central aspect of the approach is to switch forth and back between the empirical domain and the development of a structured understanding of it, in order to achieve a relevant conceptualisation and to achieve it efficiently.

This efficiency is strived towards here by not seeking statistically significant results, but by focusing on reaching a sufficient understanding for further discussions and measures.

Comparing the above described procedures of the empirically based design of this study, the sampling approach of this study might not seem feasible. Sampling is less flexible since the study objects are pre-defined after the sampling has been performed. This could result in missing important explanations that the flexibility supported by an empirically based approach encourages us to find. Also, sampling appears to lead to unnecessary work, since an understanding of several aspects may not need as many as 200 articles to be studied. However, the sampling serves the purpose of the time efficient procedure of analysing each article abstract from as many of the relevant aspects as possible at only one reading of it and thereby enabling the coverage of a larger number of articles.

The supposedly most effective and efficient approaches for reaching the aim of this empirically based study were used for the more detailed design of the study. These approaches were found to be a categorisation with discourse analysis (DA), elaborated upon in the following and being a combination of qualitative and quantitative approaches, and being complemented by identifying proxy sub fields and concepts on ‘social IE’ research.

Categorising the contents

A categorisation approach is used as a method because of the combination of an extensive and a diverse study material. In short, a number of categories for sorting the articles were identified and each article was evaluated regarding whether it ought to be seen as belonging to each of these categories. This quantification has been seen as suitable since a purely qualitative study would likely require a very extensive study not to risk to miss potentially relevant explanations.

Which types of phenomena that are considered and identified in the texts through the use of this categorisation is based on the effectiveness approach promoted by the empirically based methodology. The goal of the information

extraction is to sufficiently map key research characteristics in order to strive towards the aim of this study.

A categorisation is also in other ways well-suited for the design of this study. By basing the categorisation on the flexibility of an empirically based approach, a possible critique that we are bound to *a priori* defined categories is partly handled. In addition, the use of sampling, which was described in the previous sub chapter, seems to fit the quantitative leg of categorisation.

Discourse analysis

In order to handle changes in research language due to trends and to be able to see beyond rhetorical reasoning, the context sensitive method of *DA is* used as a background filter throughout the analysis of the publications (Silverman 2006:223-235).

3.5. Detailed design

For the full use of the empirically based approach, two sets of categories were created and they were complemented by identifying proxy sub fields and concepts on 'social IE' research.

Regarding the categories, both on IE research in general and on 'social IE' studies, these were selected to cover both relevant terms and relevant practices – in line with the IE field delimitation utilised in this study. Articles were considered to cover a certain category only if it is substantially applied to the article, including recommendations for further studies on the specific issue of the category. However, due to the use of abstracts, the short length of many studied abstract texts did not make it possible to categorise them with precision in all cases. As compensation, a 'maybe'-categorisation was used as a complement. Further, categories were added, modified and discarded during the iterations.

A few categories, that were thought to be relevant for giving an overview of the field or its social aspects research, were thus omitted in the presentations in this report. The reason was that these phenomena were relatively little explicitly stated and that the shortness of abstracts then made it difficult to practically study them through the approach used in this study. These categories include whether the social aspects are (mainly) technological systems' *impacts on humans*, or *humans' control of* these systems. Also, a categorising into articles aimed for business decision making, industry policy or public policy was eventually omitted for the same reason.

Below, the different categories used and their relevance for this study are described. The categories are grouped according to the two of the three main parts of the research design: general IE research and 'social IE' studies in general. The first steps towards studying the third part – the identified proxy sub fields and concepts on 'social IE' research – are thereafter outlined.

General industrial ecology research

This section on the analysis categories for IE in general is divided into four groups: overarching categories; categories on technology, products and flows; on environmental aspects; and finally a category on whether social aspects are covered.

The categories are also presented in two tables. A summary of the categories is found at the end of this section, in Table 2. In the Results chapter, a full listing of the categories and the results of the application of them onto the 200 sampled articles is displayed in Table 6.

Overarching

One step towards a description of the IE field used here is to categorise the articles according to the basic types of research texts. This covers, for example, case studies, method development, and discussion articles. Dividing IE articles between these types is further motivated by the mentioning of some of these categories in the aims of the five reviewed journals. Particularly, IJLCA mentions "actual LCAs", "improvement and development of LCA methodology", and "LCA workshops, symposia, conferences" (IJLCA 2011), while RCR calls for "papers, reviews, analyses and case studies on topics" (RCR 2010). In addition, the scientific study types cover many of the key concepts of science, such as theory, methodology, and method (cf Silverman 2006:13).

In total, nine categories are used, and they are presented below. They are organised in three groups – original research, in-depth studies of other research, and other study types.

Original research is here divided into user oriented studies and integrated cases. These cover finding mainly based on other sources than previously published research or being clearly distinct from the review type of article. Also, the definitions of the two categories depend on each other. The user oriented category is designed to cover research that is mainly focused on for example a commissioner's needs while putting less emphasis on being requested by and comparing its findings to other research. It was inspired by preliminary review iterations that indicated many research articles with seemingly loose connections to other research. Also, the mentioning of "actual LCAs" contrary to "case studies" in the IJLCA aims (IJLCA 2011) inspired the inclusion of this category. Integrated cases are, on the other hand, here defined as studies that put focus on being requested by or comparing its findings to other research. The category is based on Yin's definition of a case study (Yin 2009), and since reviewing the journals revealed that the term case in some instances is used for studies here categorised as user oriented, the word integrated was added for clarity. Yin's definition is targeted to the social sciences but since the aspects referred to here are about basic research principles it is assumed to be applicable to IE research as well. He describes the need to use a thorough methodology, including an extensive literature review, when performing a case study, and the need to clearly present limitations and strengths related to the choice of the case study as the research method (Yin

2009:3). In line with this, he argues that it is useful for the carrying out of the study to explicitly describe why and how the case has been chosen (Yin 2009:24).

Under the in-depth studies of other research, the four categories synthesis of cases, development of research methodology/methods, theory development, and review of research are grouped. These categories are separated from for example discussion articles, where more discussion oriented and more novel argumentations are categorised. Among the categories, synthesis of cases is defined as syntheses that focus mainly on bringing together a number of studies and with less focus on relating this to broader methodologies/methods or theory.

In the third group, three additional study types are grouped based on that they do not apply to any of the previous two groups. These categories are discussion articles, descriptions of projects, etc, and lastly editorials of special issues, or conference summaries. The discussion articles cover, as mentioned above, more discussion oriented articles where a subject is discussed more freely and with less rigid backing up from traditional research studies. The category on description of a project, etc, is designed to represent articles describing for example projects where researchers closely cooperate with industry, and where the description is in focus and little or no analysis is performed.

Technology, products and flows

In this section on technology, products and flows, the categories are designed to aid an understanding of how technology and industry are researched in IE besides their social aspects. The categories are organised in five groups, with some overlaps: maturity phases of technology and products and flows; study output; organisational focus; quantitative and qualitative approaches; and other categories.

The maturity phases of technology, products and flows are considered in order to seek an overview of the study objects in focus in IE, and to distinguish the potentially more flexible early development phases from the in society more mature technologies, products and flows. Five categories have been used, and almost all of the technically oriented articles applied to at least one of these. The categories are product design; development of new or well established or historical (focusing on a development phase); introduction of new (focusing on an introduction phase); new; and well established.

A study of the output from the IE articles is carried out in order to try to understand the form that is used for the presentation of research results. Two categories have been identified – development of evaluation tools and development of frameworks – and these were not designed to together account for all the technology oriented IE articles. Development of evaluation tools represents for example software that is constructed to provide a lower difficulty and number of options for the user than less structured evaluations would require. Development of frameworks is here associated with structured analysis procedures that are more transparent to the user than the above defined evaluation tools.

Organisational focus is designed to cover the scientific approaches regarding how many and in which way that different organisations, such as companies, are included

in the same study. Thereby, an identified link between technical and social aspects is studied. The category systems spanning several organisations basically covers whether an inter-organisational systems perspective is used, and in many cases originating in the several systems tools, such as LCA, that are common in IE. The category organisational differences guide study design but are not evaluated themselves is designed to account for the studies where a multi-organisational perspective is used to compare different organisations and where this comparison covers technical but not social aspects.

A second scientific approach that was studied was the choice of quantitative and qualitative studies, respectively. These appeared to be more difficult to distinguish from the texts than first expected. Thus, only two scarcely identified categories were formulated: the use of simulations; and qualitative conclusions. Simulations are, at least partly, quantitative by nature. They are also assumed to be large undertakings, and since they thereby tend to dominate studies, they are here considered to be of potential relevance. The presence of qualitative conclusions in the texts is evaluated in order to map qualitative approaches in the wrapping up of studies. Also, conclusions are expected to be intended for comparison to other research, and therefore represent trends in larger parts of the field.

Finally, four categories were designed to capture the extent and characteristics of technically oriented articles that are more or less not covered by the above categorisations. Articles covering technology or products or flows but none of the above eleven categories were distinguished, as well as articles where it was unclear how or whether technology or products or flows were studied. As a complement to these three categories, the articles clearly not covering technology or products or flows were identified.

Environment

In this section, the design of the study of explicit environmental aspects in the articles is presented. Only environmental aspects that are explicit are considered since it is difficult to distinguish between aspects that are implicit and not related to the biophysical environment. Also, a screening performed in this study showed that all or almost all of the articles reviewed here were, not surprisingly, found to explicitly or more or less implicitly cover environmental aspects. Thus, a focus on only the environmental aspects that are explicit is considered to offer a more nuanced picture of the focuses of the articles.

The categories used for studying environmental aspects in the articles are sorted into four groups. As for the technically oriented aspects, some overlaps occur between these groups. The groups are: closeness to nature, output from the studies, scientific approach, and other aspects.

Categories on the closeness to nature are included for two main reasons. First, they are designed for the study of whether or to which extent the approach to environmental aspects in IE research differ from the above mentioned limited coverage of these in the neighbouring field of CEM studies. Thereby indications of potential differences between IE research and environmental social science and the

corresponding difficulties to exchange knowledge when fundamental differences exist are sought. Second, and partly contrasting the previous reason, increasing closeness to nature in studies is assumed to be a driver for bridging to other fields related to studying environmental aspects since a close study of the actual states of nature could inform the researcher more clearly about the degree of potential needs for further actions. Seven categories are used: explicit states of nature; risks assessed and thus evaluation of potential threats; time aspects such as in the sustainability concept; impact assessments or similar, such as global warming potential; inventory analysis or similar, such as CO_2 emissions; flows in regular use, such as recycling; and the unclear cases of whether flows in regular use, such as recycling, is studied. No absolute hierarchy is supposed to exist between these categories, but, generally, the former ones are designed to represent a higher degree of closeness to nature than the latter ones. The categories on flows in regular use are included in order to represent flows, such as recycling, that directly affect factors external to the socio-technical parts of society but where these relationships are not explicitly studied.

Similar to the technically oriented aspects focussed on in the above section, a study is here carried out of the output from the IE articles in order to understand the form that is used for the presentation of research results. The same two categories as for the technically oriented aspects have been identified – development of evaluation tools and development of frameworks – and these are treated in the same way as in that section.

A category relating to scientific approach is designed to map whether more than one environmental issue, such as energy use and eutrophication, are included in the same study. This gives information about any attempt for completeness regarding coverage of the range of environmental issues.

Finally, and also similar to the technically oriented studies, four categories were designed to capture the extent and characteristics of explicitly environmentally oriented articles that are more or less not covered by the above categorisations. Articles covering environmental aspects but none of the above ten categories are distinguished, as well as articles where it is unclear how or whether explicitly environmentally oriented aspects are studied. As a complement to these three categories, the articles clearly not covering explicitly environmentally oriented aspects are identified.

Whether social aspects are studied

In this overview of IE research in general, the articles clearly or maybe covering social aspects are also included in order to give a more complete picture of the field. The ones clearly covering social aspects are further analysed using the framework presented in the following section.

Table 2: Extract of framework for analysing industrial ecology studies in general

Main sections	Sub sections	Examples of detailed result categories
Type of study	Original research	- User oriented (relatively large focus on the user and less on the relation to other research)
	In-depth studies of other research	- Review of research
	Other	- Editorial of special issue, or conference summary
How technology/products/flows are studied		
Study objects	Maturity phase of technology/products/flows	- Product design - Introduction of new
Output		- Development of evaluation tool - Development of framework
Scientific approach	Organisational focus	- System spanning several organisations
	Quantitative/qualitative	- Simulation used
Other		- Not studied
How the environment is studied		
Study objects	Closeness to nature	- Explicit states of nature - Inventory analysis, e.g. CO_2 emissions
Output		- Development of evaluation tool - Development of framework
Scientific approach		- System covering several environmental issues
Other		- Not studied
If social aspects are studied		

Studies on social aspects in industrial ecology in general

Here, the general 'social IE' research aspects covered in this study are described. They are, in addition to the above described general framework, applied to the articles in the random sample that were found to clearly cover social aspects. The analysis categories used were divided into ten groups. A few of these are overlapping, and a few are similar to the ones used for the general framework presented above. The groups cover: whether the social aspects are about economy or about education as a study object, respectively, whether the social aspects are related to other study objects,

quantification of relations between social aspects and other study objects, integration of social aspects to other study objects, output from the studies, quantitative or qualitative approaches, use of social theory, paradigms, and other aspects. These groups are further described in the following and summarised in Table 3, and fully listed together with the results from the application of them to the 98 sampled articles identified to cover social aspects in Table 7.

Economic aspects were one out of two types of study objects that could be clearly distinguished. The relevance of studying economic aspects here in order to understand the autonomy of the field could be exemplified by a comparison that has been performed between IE research and the neighbouring field ecological economics and that resulted in the conclusion that IE can be seen as a sub field to ecological economics (see Kronenberg 2006). Due to the apparent importance of economic aspects in IE studies, and due to the varying extent of the social aspects that were found to be of an economic nature in the different articles reviewed, a further division into five categories was made based on this extent. The categories refer to the extent that the social aspects covered are on economic aspects, and they are: fully, between fully and partly, partly, between partly and not, and not.

The second study object that has been clearly identified is education. JCP explicitly lists education, training and learning as one of the journal's sections (JCP 2010).

The relations studied between social aspects and other study objects are included from three different perspectives in order to map the combinations of different knowledge types and the approaches used for these combinations. First, the existence of such combinations is studied. The dividing of these study objects is based on the three main areas used throughout this study – technically oriented, environmental, and social aspects. The relating between different social aspects is included in order to show the extent of covering more than one social aspect in each article. Scientific knowledge is included as a separate category since it was identified in the articles and since it is considered not to be covered by any of the above three ones. Finally, a fifth category on unclear information about to which study objects that the social aspects are related is used to reflect an identified vagueness of the study of social aspects.

Second, the relations between social aspects and other study objects are mapped regarding quantitative comparisons. This could be numeric matrix evaluations such as multi-criteria analysis (MCA). This group covers the three main study object categories listed for the previous group, since these were the identified ones.

Third, social aspects' integration to other study objects is covered. Integration here refers to describing the shape of these relations, contrary to listing the different study objects next to each other without further study of their relations. Similarly to the previous group, the three categories of technically oriented, environmental, and social aspects were identified and mapped.

Similar to the technically oriented and environmental aspects above, a study is here carried out of the output from the articles in order to understand the form that is used for the presentation of research results on social aspects. Three categories have been identified – the already in the above section on technically oriented aspects described

development of evaluation tools and development of frameworks, as well as recommendations for further studies – and these were not designed to together account for all the 'social IE' articles. The extent of recommendations for further studies is assumed to reflect the strength of relations between different research endeavours.

Similar to the studies of technically oriented aspects, the scientific approach regarding the choice between quantitative and qualitative studies was here covered. The two categories that were identified as applicable were quantified conclusions or clearly quantitative intermediate steps, and qualitative conclusions, respectively. Quantitative approaches were found to be relatively easy to identify not only regarding the final conclusions in articles, contrary to qualitative approaches. The presence of qualitative conclusions in the texts is evaluated in order to map qualitative approaches in the wrapping up of studies. Also, conclusions are expected to be intended for comparison to other research and therefore represent trends in larger parts of the field.

In order to more directly compare the practices of 'social IE' research to research practices in the social sciences, the use of social theory was studied. The articles were identified to use social theory to varying degrees in their coverage of social aspects, and therefore three categories were used regarding this extent: fully, partly, and not.

A second more direct comparison to the social sciences is carried out via paradigms. This is performed through just one of these disciplines – organisation studies. The reason for choosing only this discipline is its broad range of coverage of scientific approaches, theories, methods, and study objects (cf Hatch 2006:5), compared to the more narrow coverage in for example sociology (see e.g. the sociology textbook by Bauman and May, 2004). Such broad perspectives are also not covered in any general overview of disciplines known to us. Also, organisation studies is one of the disciplines that IE research most clearly attempts to bridge towards. The specific evaluation here performed is based on a division into four paradigms, approximately historically sequenced, which are outlined in the organisation theory textbook by Hatch (2006). The paradigms are, and with Hatch's terminology stated within brackets when a different term is chosen than Hatch uses: unit focus (pre-modern approaches), complexity (modernism), symbolic-interpretive perspective, and postmodernism. The first one refers to the study types that spurred the creation of organisation theory (its pre-history) (Hatch 2006:27). It mainly consists of two perspectives: treating organisations as held together units, and aligning to issues of the daily work of managers, respectively (Hatch 2006:27). The complexity approach (modernism) takes a step further by studying organisations more in detail, but keeping the objectivist and positivist stance from the unit approaches. This basis is developed by the symbolic-interpretive proponents (their approach is also labelled constructivism), who account for subjectivity and who believe that the effect of actions rather depend on the subjective satisfaction of the involved persons than on the rationality of the

action in itself. A further differentiation is made by the postmodernists, whose epistemology foundation is that no facts exist, but only interpretations, and that knowledge thus is a play about power. (Hatch 2006:14)

Finally, and also similar to the technically oriented and environmental aspects, two categories were designed to capture the articles that are more or less not covered by the above categorisations. 'Social IE' articles covering none of the above 29 categories are distinguished, as well as articles where it is unclear how social aspects are studied.

Table 3: Extract of framework for analysing studies on social aspects in industrial ecology

Main sections	Sub sections	Examples of detailed result categories
Study objects	If the social aspects are about economy	
	Education	
Relation to other study objects	Related to…	- …Technology/products/flows - …The environment - …Other social aspects
	Quantification of relation to…	
	Integration to…	
Output		- Development of evaluation tool - Development of framework
Scientific approach	Quantitative/qualitative	- Quantified conclusions or clearly quantitative intermediate steps - Qualitative conclusions
	Use of social theory	
	Paradigm	- Complexity (rational and modernist) - Postmodernism, i.e. critical dissemination of especially social power structures
Other		- None of the above

Proxy sub areas in and concepts on social aspects in industrial ecology

The common criterion used here for determining 'social IE' concepts of relevance is that a substantial number of articles use the same or similar specific key terms. Further, and in addition to the level of focus on method aspects in relation to these concepts, the concepts are grouped according to the extent that they focus on the social aspects in question. This is used as a grouping criterion since the degree of understanding of 'social IE' research is sought for.

Four in these aspects particularly central ‘social IE’ concepts were found and they are therefore treated as proxies of sub areas, with further studies of them in order to emphasise their origins and anatomies. In addition to the descriptive value of such a mapping, a basis for understanding possible future developments of research on ‘social IE’ research is thereby sought for.

Nine concepts that to a lesser degree apply to the centrality to IE criterion were also identified. These are listed in this study, and briefly analysed, in order to give a broader picture of the field’s research on social aspects.

3.6. Further analysis

All of the above described categories in the two frameworks and ‘social IE’ proxy sub areas and concepts where used to create an overview of the studied material, while only those parts that were found to be of special interest were used for the analysis that lies behind the presentation in the Analysis chapter.

3.7. Research tools

The scientific database Scopus was used for retrieving bibliographic information, including abstracts, for a majority of the articles included in this literature review. A few publication years and issues for some of the five journals were not covered by Scopus, and these were retrieved manually.

An EndNote library was then used for searching and categorising the articles, and this library did not include full-texts.

4. Results

In this chapter, an overview of the publication patterns of the journals, and basic quantitative results from applying the above described method are presented.

4.1. Publication patterns of the five journals

The publication patterns of the five reviewed journals can be summarised as steadily growing since the start in 1988 and new journals were mainly launched during the first ten years, which is also presented through overviews in Table 4 and Figure 2a. RCR and JCP are the longest running ones of the journals, being published since 1988 and 1993, respectively, and followed by IJLCA in 1996, JIE in 1997, and PIE in 2004. All journals except PIE show trends of increasing annual numbers of abstracted articles during the period here studied. In general, the annual numbers of abstracted articles are higher for the longer running of these journals, except for JCP which is the most rapidly growing of the five journals in this aspect, which is also illustrated by Figure 2a.

The number of abstracted articles is considered to be a representative measure here. This is based on the large share of the articles being abstracted, as described above, and on that a screening, performed for this purpose during this study, of the journals showed that the article sizes are almost constant during this time period within each of the five journals.

One deviation from a constant increase in the number of published abstracted articles can be seen in the year 2009. Two of the journals, RCR and JCP, published fewer articles this year than during both the preceding and the following year. They have published the same number of issues per year during this three year period and the amount of non-abstracted articles does not show any signs to account for the temporary decrease. What can be seen, is that the around 2009 most fluctuating of these two journals, RCR, published fewer number of pages in 2011 than in 2010, but not much, showing a longer term rise with short term fluctuations. Particularly, in the end of 2010, three out of four consecutive issues – issues 11 and 12 of volume 54, and issue 2 of volume 55 – contained a much higher number of pages than the average issue, together having an average of 297 pages compared to 132 pages on average per issue during the entire period of 2008-2010. No introductory comments to each issue have been found in RCR to explain this situation, and no obvious reasons such as special issues have been found to be at hand.

In addition to the launch years and number of abstracted articles, some ranking information is presented here to give an additional overview perspective. The standard rating measure – the impact factors published in the Thomson Reuters Journal Citations Reports – are presented according to the information provided by the journals' web pages. It is based on the average number of citations of each article in journals, and it ranges between 1.9 and 2.6 for the year 2009 for all of the journals

here reviewed besides PIE. No impact factors are available for PIE, and, based on the citation patterns presented in Table 1, such an impact factor could be assumed to be considerably lower than for the other four journals. Additional, from the journal web pages available, Thomson Reuters based statistics on the journals' ranks within certain research sections provides further information. In the sector "engineering, environmental" IJLCA holds rank 9 out of 42, and JIE holds rank 51 out of and IJLCA rank 37 out of 180 in "environmental sciences", all in 2009. The information is summarised in Table 4.

An overview is also given here for the 200 sampled articles, to facilitate comparisons between them and the entirety of the journals. As presented in Table 5, the numbers of articles sampled from each of the journals vary between 69 for JCP and 10 for PIE. The percentage of abstracted articles sampled in each journal range between 3.1% for JIE and 6.0% for PIE, and averaging 4.4% for all of the 200 sampled articles, as also presented in Table 5. A more detailed visualisation of journals and years sampled is found in Figure 2b. Some, but not large variations, can there be seen and are also to be expected from the moderate size of the sample.

Table 4: Overview of the reviewed journals

Journal	**Published since**	**Abstracted papers until and including 2010**	**Impact factors 2009, in Thomson Reuters Journal Citations Reports***		
		Number of	Impact factor	Rank in Environmental sciences	Rank in Engineering, environmental
Journal of Industrial Ecology	1997	478	2.4	51/180	
Progress in Industrial Ecology	2004	166			
International Journal of Life Cycle Assessment	1996	726	2.6	37/180	9/42
Journal of Cleaner Production	1993	1,667	1.9		
Resources, Conservation & Recycling	1988	1,470	2.0		
Total		4,507			

* All available information from the journal's web pages is here displayed. No other sources were used.

Table 5: Overview of the sampled articles

	Sampled abstracted articles	
	Number of	Percentage of each journal's number of abstracted articles
Journal of Industrial Ecology	15	3.1
Progress in Industrial Ecology	10	6.0
International Journal of Life Cycle Assessment	40	5.5
Journal of Cleaner Production	69	4.1
Resources, Conservation & Recycling	66	4.5
Total	200	4.4

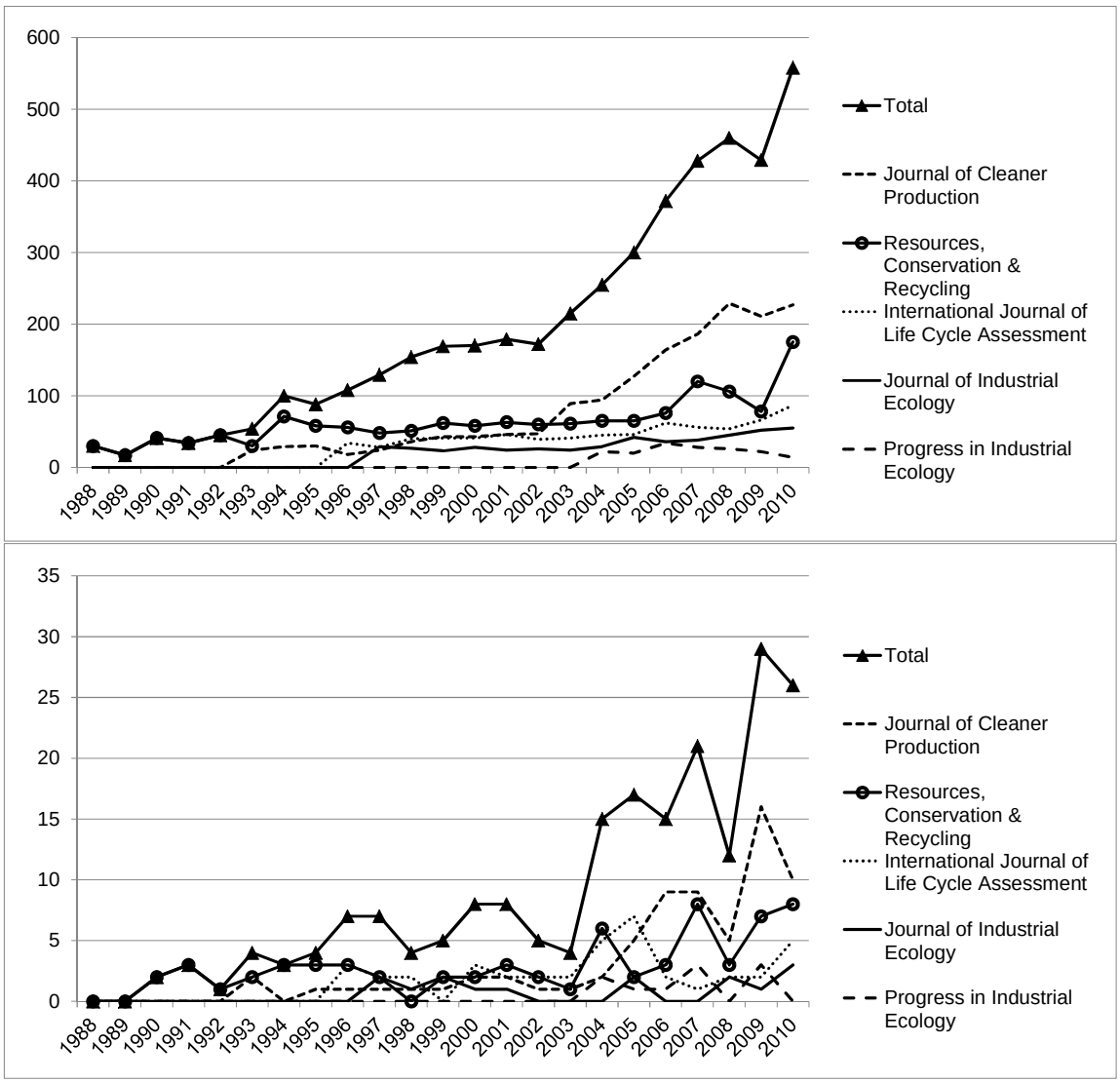


Figure 2a and Figure 2b: Number of abstracted articles in the reviewed journals each year, in total (a) and sampled (b). Sums included ('triangle' curves).

4.2. Applying the two frameworks

In this section quantitative results from categorising the 200 sampled articles are presented. All categories described in sub chapter 3.5. are presented in two tables here – Table 6 for the general IE research aspects of all the 200 sampled articles, and Table 7 for the social aspects of the 98 of these articles that were identified as clearly covering social aspects. Three figures are displayed for each category: the number of articles clearly applying to the category, those maybe applying to it, and the sum of these two figures. Also, the titles of randomly sampled example articles are listed for each category in these tables. Detailed descriptions are only be given for a few of

these results in the next chapter, to sort out the in our view most relevant and illustrative findings. For detailed quantitative results for each of the 200 articles, see Table A.2 and Table A.1 in the Appendix.

Table 6: Results of the framework for evaluating industrial ecology research in general, applied to all 200 sampled articles

Main sections	Sub sections	Detailed result categories	Yes	May-be	Sum: Yes or maybe	Example articles, clearly attributed to the category
I.A. Type of study	1. Original research	a. User oriented (relatively large focused on the user, and less on the relation to other research if that is not covered by one or more other categories)	75%	3%	78%	Insa et al (2010) Critical review of medical waste legislation in Spain. RCR 54(12):1048-59. Karavanas et al (2009) Evaluation of the implementation of best available techniques in IPPC context: An environmental performance indicators approach. JCP 17(4):480-6. Lee et al (2010) A hierarchical end-of-life decision model for determining the economic levels of remanufacturing and disassembly under environmental regulations. JCP 18(13):1276-83.
		b. Integrated case (relatively large focus on the relation to other research)	9%	0%	9%	Toffoleto et al (2005) LCA of ex-situ bioremediation of diesel-contaminated soil. IJLCA 10(6):406-16.
	2. In-depth studies of other research	a. Synthesis of cases	2%	0%	2%	Korhonen et al (2004) Editorial: Towards progress in industrial ecology. PIE 1(1-3):1-23.
		b. Development of research methodology/ methods	11%	0%	11%	Dubreuil et al (2010) Metals recycling maps and allocation procedures in life cycle assessment. IJLCA 15(6):621-34. Kremer et al (1998) Waste treatment in product specific life cycle inventories: An approach of material-related modelling: Part I: Incineration. IJLCA 3(1):47-55.
		c. Theory development	0%	0%	0%	-
		d. Review of research	2%	0%	2%	Björklund et al (2005) Recycling revisited - Life cycle comparisons of global warming impact and total energy use of waste management strategies. RCR 44(4):309-17.
	3. Other	a. Discussion	9%	3%	12%	Shapiro (2001) Incorporating costs in LCA. IJLCA 6(2):121-3.
		b. Description of a project, etc	9%	2%	11%	Molander et al (2004) OMNIITOX - Operational life-cycle impact assessment models and information tools for practitioners. IJLCA 9(5):282-8.
		c. Editorial of special issue, or conference summary	3%	-	3%	Korhonen et al (2004) Editorial: Towards progress in industrial ecology. PIE 1(1-3):1-23.
II. How technology/products/flows are studied:						
A. Study objects	1. Maturity phase of technolo-gy/ products/ flows	a. Product design	1%	0%	1%	Leibrecht (2005) Fundamental principles for CAD-based ecological assessments. IJLCA 10(6):436-44.
		b. Development of new/well established/ historical	14%	3%	17%	Castillo Berthier (2003) Garbage, work and society. RCR 39(3):193-210. Pfeifer (1996) Comparison between filament lamps and compact fluorescent lamps. IJLCA 1(1):8-14.

		c. Introduction of new	9%	1%	9%	D'Alessandro et al (2010) Energy transition towards economic and environmental sustainability: feasible paths and policy implications. JCP 18(6):532-9.
		d. New	19%	1%	20%	Badawi et al (1992) Production of acetic acid from thermally treated sewage sludge in an upflow anaerobic reactor. RCR 7(1-3):201-12. Dimitroff-Regatschnig et al (1998) A techno-economic approach to link waste minimization technologies with the reduction of corporate environmental costs: Effects on the resource and energy efficiency of production. RCR 6(3-4):213-25.
		e. Well established	36%	0%	36%	Alonso-Santurde et al (2010) Valorization of foundry sand in clay bricks at industrial scale. JIE 14(2):217-20. Owens (1997) Life-cycle assessment: Constraints on moving from inventory to impact assessment. JIE 1(1):37-49.
B. Output		1.a. Development of evaluation tool	9%	2%	11%	Karavanas et al (2009) Evaluation of the implementation of best available techniques in IPPC context: An environmental performance indicators approach. JCP 17(4):480-6.
		1.b. Development of framework	1%	1%	2%	Arbiza et al (2008) Metaheuristic multiobjective optimisation approach for the scheduling of multiproduct batch chemical plants. JCP 16(2):233-44.
C. Scientific approach	1. Organi-sational focus	a. System spanning several organisations	39%	2%	41%	Bergsdal et al (2005) Environmental assessment of two waste incineration strategies for Central Norway. IJLCA 10(4):263-72. Weinzettel et al (2009) Assessing socioeconomic metabolism through hybrid life cycle assessment: The case of the Czech Republic. JIE 13(4):607-21.
		b. Organisational differences guide study design but are not evaluated themselves	14%	3%	17%	Davis et al (2008) Electronic waste: The local government perspective in Queensland. RCR 52(8-9):1031-9. Fehr et al (2000) A practical solution to the problem of household waste management in Brazil. RCR 30(3):245-57.
	2. Quantita-tive/ qualitative	a. Simulation used	4%	1%	5%	Matsuno et al (2000) Development of life cycle inventories for electricity grid mixes in Japan. IJLCA 5(5):295-305.
		b. Qualitative conclusions	1%	0%	1%	Fratila (2009) Evaluation of near-dry machining effects on gear milling process efficiency. JCP 17(9):839-45.
D. Other		1.a. Studied but none of the above	2%	-	2%	Tramšek et al (2007) Methodology for determination of anaerobic digestion kinetics using a bench top digester. RCR 51(1):225-36.
		1.b. Unclear how it is studied	9%	2%	11%	Schmidt et al (2004) A comparative life cycle assessment of building insulation products made of stone wool, paper wool and flax: Part 1: Background, goal and scope, life

						cycle inventory, impact assessment and interpretation. IJLCA 9(1):53-66.
		1.c. Unclear whether it is studied	5%	-	5%	Korhonen (2005) Theory of industrial ecology: The case of the concept of diversity. PIE 2(1):35-72.
		1.d. Not studied	15%	-	15%	Bengtsson et al (2004) Actors and interpretations in an environmental controversy: The Swedish debate on sewage sludge use in agriculture. RCR 42(1):65-82. Meech et al (2006) Transformation of a derelict mine site into a sustainable community: The Britannia project. JCP 14(3-4):349-65.
III. How the environment is studied:						
A. Study objects	1. Closeness to nature	a. Explicit states of nature	0%	0%	0%	-
		b. Risks assessed, and thus evaluating potential threat	2%	2%	4%	Morris et al (2008) Measuring environmental value for natural lawn and garden care practices. IJLCA 13(3):226-34.
		c. Time aspects such as in the sustainability concept	2%	1%	2%	D'Alessandro et al (2010) Energy transition towards economic and environmental sustainability: Feasible paths and policy implications. JCP 18(6):532-9.
		d. Impact assessment, e.g. global warming potential	25%	1%	26%	Muñoz e al (1996) Using LCA to assess eco-design in the automotive sector: Case study of a polyolefinic door panel. IJLCA 11(5):323-34. Pfeifer (1996) Comparison between filament lamps and compact fluorescent lamps. IJLCA 1(1):8-14.
		e. Inventory analysis, e.g. CO_2 emissions	13%	2%	15%	Kløverpris et al (2008) Conference and workshop on modelling global land use implications in the environmental assessment of biofuels. IJLCA 13(3):178-83. Ren et al (2009) Basic petrochemicals from natural gas, coal and biomass: Energy use and CO2 emissions. RCR 53(9):513-28.
		f. Flows in regular use, e.g. recycling	5%	-	5%	Heiskanen et al (2009) Policies to promote sustainable consumption: Framework for a future-oriented evaluation. PIE 6(4):387-403.
		g. Unclear if flows in regular use, e.g. recycling, is studied	3%	-	3%	Sharma et al (1997) Environmental and economic policy analysis of waste paper trade and recycling in India. RCR 21(1):55-70.
B. Output		1.a. Development of evaluation tool	8%	2%	10%	Allwood et al (2008) An approach to scenario analysis of the sustainability of an industrial sector applied to clothing and textiles in the UK. JCP 16(12):1234-46.
		1.b. Development of framework	2%	1%	2%	Heiskanen et al (2009) Policies to promote sustainable consumption: Framework for a future-oriented evaluation. PIE 6(4):387-403.

C. Scientific approach		1.a. System covering several environmental issues	23%	3%	26%	Burgess et al (2001) Desulfurisation of gas oil: A case study in environmental and economic assessment. JCP 9(5):465-72. Maurice et al (2000) Uncertainty analysis in life cycle inventory. Application to the production of electricity with French coal power plants. JCP 8(2):95-108.
D. Other		1.a. Studied but none of the above	2%	-	2%	Wilson et al (2007) Kerbside collection: A case study from the north-west of England. RCR 52(2):381-94.
		1.b. Unclear how it is studied	7%	2%	9%	Korhonen et al (2004) Editorial: Towards progress in industrial ecology. PIE 1(1-3):1-23.
		1.c. Unclear whether it is studied	6%	-	6%	Haibin et al (2010) Recycling utilization patterns of coal mining waste in China. RCR 54(12):1331-40.
		1.d. Not studied	40%	-	40%	Brent et al (2002) Status of life cycle assessment and engineering research in South Africa. IJLCA 7(3):167-72. Inada et al (2001) Identification of plastics by infrared absorption using InGaAsP laser diode. RCR 33(2):131-46.
IV. If social aspects are studied						
			49%	9%	57%	Kronenberg (2006) Industrial ecology and ecological economics. PIE 3(1-2):95-113. Wagner et al (2008) A new model for solid waste management: An analysis of the Nova Scotia MSW strategy. JCP 16(4):410-21.

Table 7: Results of the framework for evaluating research in industrial ecology on social issues, applied to the 98 articles of the sample that cover social aspects

Main sections	Sub sections	Detailed result categories	Yes	May-be	Yes or maybe	Example articles, clearly attributed to the category
V.A. Study objects	1. If the social aspects are about economy	a. Fully	21%	-	21%	Burgess et al (2001) Desulfurisation of gas oil: A case study in environmental and economic assessment. JCP 9(5):465-72. Shapiro (2001) Incorporating costs in LCA. IJLCA 6(2):121-3.
		b. Between fully and partly	3%	-	3%	Lave et al (1998) Recycling postconsumer nylon carpet: A case study of the economics and engineering issues associated with recycling postconsumer goods. JIE 2(1):117-26.
		c. Partly	26%	-	26%	Grigg et al (2001) A discussion on the various methods of application for landfill tax credit funding for environmental and community projects. RCR 32(3-4):389-409. Sharma et al (1997) Environmental and economic policy analysis of waste paper trade and recycling in India. RCR 21(1):55-70.
		d. Between partly and not	9%	-	9%	Baumgartner et al (2007) Analyzing zero emission strategies regarding impact on organizational culture and contribution to sustainable development. JCP 15(13-14):1321-7.
		e. Not	41%	-	41%	Bitterman et al (2009) Using strategic sustainable development as an approach to conflict resolution. PIE 6(3):314-34. Ceulemans et al (2010) Teacher's manual and method for SD integration in curricula. JCP 18(7):645-51.
	2. Education		7%	0%	7%	Steiner et al (2006) Higher education for sustainability by means of transdisciplinary case studies: an innovative approach for solving complex, real-world problems. JCP 14(9-11):877-90.
V.B. Relation to other study objects	1. Related to…	a. …Technology/ products/flows	53%	7%	60%	Abd El-Salam et al (2010) In-plant control for water minimization and wastewater reuse: A case study in pasta plants of Alexandria Flour Mills and Bakeries Company, Egypt. JCP 18(14):1403-12. Sibley et al (1995) Metals recycling in the United States. RCR 15(3-4):259-67. Weinzettel et al (2009) Assessing socioeconomic metabolism through hybrid life cycle assessment: The case of the Czech Republic. JIE 13(4):607-21.
		b. …The environment	38%	5%	43%	Pye et al (2000) Making a stronger case for industrial energy efficiency by quantifying non-energy benefits. RCR 28(3-4):171-83. Zah et al (2007) Curauá fibers in the automobile industry - a sustainability assessment. JCP 15(11-12):1032-40.

		c. …Other social aspects	57%	5%	62%	Hansen et al (2006) Agents of change: universities as development hubs. JCP 14(9-11):820-9. Kurczewski et al (2010) ISO 14062 in theory and practice-ecodesign procedure. Part 2: Practical application. IJLCA 15(8):777-84. Maxwell et al (2006) Functional and systems aspects of the sustainable product and service development approach for industry. JCP 14(17):1466-79.
		d. …Scientific knowledge	5%	1%	6%	Honkasalo (2007) Work and eco-efficiency: Opportunities and limitations. PIE 4(6):484-94.
		e. …Unclear	8%	-	8%	Helland et al (2008) Precaution in practice: Perceptions, procedures, and performance in the nanotech Industry. JIE 12(3):449-58.
	2. Quantifi-cation of relation to…	a. …Technology/ products/flows	8%	4%	12%	Lee et al (2010) A hierarchical end-of-life decision model for determining the economic levels of remanufacturing and disassembly under environmental regulations. JCP 18(13):1276-83.
		b. …The environment	8%	5%	13%	Allwood et al (2008) An approach to scenario analysis of the sustainability of an industrial sector applied to clothing and textiles in the UK. JCP 16(12):1234-46.
		c. …Other social aspects	2%	5%	7%	Skouloudis et al (2010) Assessing non-financial reports according to the Global Reporting Initiative guidelines: Evidence from Greece. JCP 18(5):426-38.
	3. Integration to…	a. …Technology/ products/flows	10%	1%	11%	Baldwin et al (2004) Modelling industrial ecosystems and the "problem" of evolution. PIE 1(1-3):39-60. Morris et al (2008) Measuring environmental value for natural lawn and garden care practices. IJLCA 13(3):226-34.
		b. …The environment	8%	1%	9%	Nishioka et al (2005) A risk-based approach to health impact assessment for input-output analysis. Part 2: Case study of insulation. IJLCA 10(4):255-62.
		c. …Other social aspects	1%	0%	1%	Tudor et al (2007) Linking intended behaviour and actions: A case study of healthcare waste management in the Cornwall NHS. RCR 51(1):1-23.
V.C. Output		1.a. Development of evaluation tool	13%	2%	15%	Arbiza et al (2008) Metaheuristic multiobjective optimisation approach for the scheduling of multiproduct batch chemical plants. JCP 16(2):233-44. Baldwin et al (2004) Modelling industrial ecosystems and the "problem" of evolution. PIE 1(1-3):39-60.
		1.b. Development of framework	4%	0%	4%	Gao et al (2006) Education for regional sustainable development: Experiences from the education framework of HHCEPZ project. JCP 14(9-11):994-1002.

		1.c Further study recommended	3%	0%	3%	Kløverpris et al (2008) Conference and workshop on modelling global land use implications in the environmental assessment of biofuels. IJLCA 13(3):178-83.
V.D. Scientific approach	1. Quantita-tive/ qualitative	a. Quantified conclusions or clearly quantitative intermediate steps	52%	5%	57%	Forslind (2005) Implementing extended producer responsibility: The case of Sweden's car scrapping scheme. JCP 13(6):619-29. Lave et al (1998) Recycling postconsumer nylon carpet: A case study of the economics and engineering issues associated with recycling postconsumer goods. JIE 2(1):117-26. Lee et al (2010) A hierarchical end-of-life decision model for determining the economic levels of remanufacturing and disassembly under environmental regulations. JCP 18(13):1276-83.
		b. Qualitative conclusions	54%	3%	57%	Costa et al (2006) An interdisciplinary approach to integrating sustainability into mining engineering education and research. JCP 14(3-4):366-73. Liu et al (2009) Determinant factors of corporate environmental information disclosure: An empirical study of Chinese listed companies. JCP 17(6):593-600. Waldron et al (2009) Strategic leadership towards sustainability: A master's programme on sustainability. PIE 6(3):307-13.
	2. Use of social theory	a. Fully	3%	1%	4%	Williams et al (2008) A life cycle perspective on environmental effects of customer focused packaging development. JCP 16(7):853-9.
		b. Partly	1%	3%	4%	Skouloudis et al (2010) Assessing non-financial reports according to the Global Reporting Initiative guidelines: Evidence from Greece. JCP 18(5):426-38.
		c. Not	92%	0%	92%	Hansen et al (2006) Agents of change: Universities as development hubs. JCP 14(9-11):820-9. Kronenberg (2006) Industrial ecology and ecological economics. PIE 3(1-2):95-113. Shapiro (2001) Incorporating costs in LCA. IJLCA 6(2):121-3.
	3. Paradigm	a. Unit focus (rational and pragmatic)	58%	1%	59%	Godfrey et al (2009) Greywater reuse in residential schools in Madhya Pradesh, India-A case study of cost-benefit analysis. RCR 53(5):287-93. Korhonen et al (2004) Editorial: Towards progress in industrial ecology. PIE 1(1-3):1-23. Meech et al (2006) Transformation of a derelict mine site into a sustainable community: The Britannia project. JCP 14(3-4):349-65.
		b. Complexity (rational and modernist)	40%	2%	42%	Gold et al (2009) Consumer attitudes towards timber as a construction material and towards timber frame houses - selected

						findings of a representative survey among the German population. JCP 17(2):303-9. Tudor et al (2007) Linking intended behaviour and actions: A case study of healthcare waste management in the Cornwall NHS. RCR 51(1):1-23.
		c. Symbolic-interpretive perspective	0%	0%	0%	-
		d. Postmodernism (critical dissemination of especially social power structures)	0%	0%	0%	-
V.E. Other		1.a. None of the above	0%	-	0%	-
		1.b. Unclear how it is studied	13%	-	13%	Veiga et al (2009) Mill leaching: A viable substitute for mercury amalgamation in the artisanal gold mining sector? JCP 17(15):1373-81. Wagner et al (2008) A new model for solid waste management: An analysis of the Nova Scotia MSW strategy. JCP 16(4):410-21.

5. Analysis

The findings from a further analysis of the results presented in the previous chapter are here described. The focus is on descriptive accounts of the articles behind the results figures, but first three quantitative views of the field are presented. They form a continuation of the overview of publication patterns in the Results chapter. They illustrate the numbers and shares of articles that were found to cover social and economic aspects, respectively. These overviews, and also the subsequent findings, are based on the categorisation frameworks applied to the sampled articles, but to illustrate the here used categories further, examples of coverage of social as well as economic aspects are given in the third sub chapter. This is followed by a description of the different study types identified in the sample. The description is thorough in order to account for all of the many categories used for organising the study types. Also, the extensive character of this sub chapter was chosen in order to assist the readers interested in evaluating the usefulness of the general method of this study. Three more issues are presented after this sub chapter, covering the use of social theory, the paradigms present, and the origin and anatomy of the identified proxy sub fields of and concepts on 'social IE' research.

5.1. Social aspects most frequent in the major and minor journals

As a starting point for an analysis of the results from this study, the journals are here compared regarding their shares of the abstracted articles in the five journals until and including 2010 in general and on social aspects, as illustrated in Figure 3. Notably, the levels of articles on social aspects are higher than the average in JCP which cover 51% of the articles on social aspects and 37% of the five journals' abstracted articles and in PIE which cover 7% of the articles on social aspects and 4% of the five journals' abstracted articles. In the other three journals this level is lower than the average and this is most clear for IJLCA which cover 8% of the articles on social aspects and 16% of the five journals' abstracted articles.

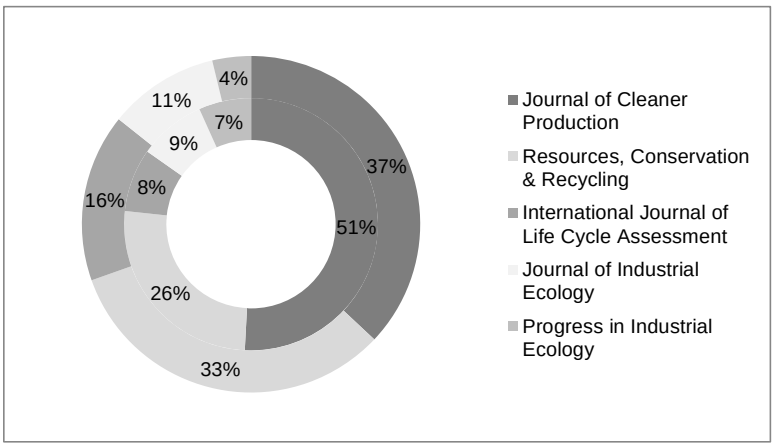


Figure 3: Shares of industrial ecology articles in general and on social aspects. Outer ring shows each journal's share of the number of abstracted articles in the five journals until and including 2010. Inner ring shows each journal's share of the number of abstracted articles on social aspects in the five journals until and including 2010

5.2. Growing amount of research on social, economic, and other aspects

In order to visualise the temporal trends regarding the number of published articles covering social and economic aspects, respectively, five different sets have been used. These are: 1. no social aspects, 2. unclear whether social aspects are studied, 3. social aspects that are entirely economic, 4. social aspects that are partly economic, and 5. social aspects that are not economic. All of these besides the first and the fourth set directly correspond to categories in Table 6 and Table 7. The fourth set corresponds to the three categories between fully and no economic focus in Table 7, since this set represent all identified seeming to be mixes of economic and other social aspects. Finally, the first set represents the remaining articles.

Normalising these sets of sampled categories to the total number of abstracted articles during three year intervals shows that each of these sets represents a considerable number of articles, as illustrated in Figure 4. The number of articles in these normalised accounts clearly covering social aspects is a little higher than the number of articles clearly not covering social aspects, amounting to 49% or around 2200 articles for the former ones and to 43% or approximately 1900 articles for the latter ones. The remaining 9% or ca 400 out of circa 4500 articles represent the ones that could not clearly be categorized as either covering social aspects or not from only studying their abstracts.

Among the articles clearly covering social aspects, the two largest sets are almost of the same size. The set representing social aspects without economic coverage amounts to 41% of the articles covering social aspects or approximately 900 articles. The second largest of these three sets cover social aspects partly being economic, and amounts to 38% or circa 830 articles. The additional 21% or around 460 articles represent articles where the social aspects covered are entirely economic.

Also, each of these five sets almost constantly increases during the studied time period, when divided into three-year groups as for the above reasoning, as Figure 4 illustrates. Some fluctuations occur, which could be expected considering the moderate number of sampled articles. However, the number of articles either covering social aspects or not, respectively, both continuously increase when using this form of illustration method, regardless of how the articles that could not clearly be categorized as either covering social aspects or not are accounted for.

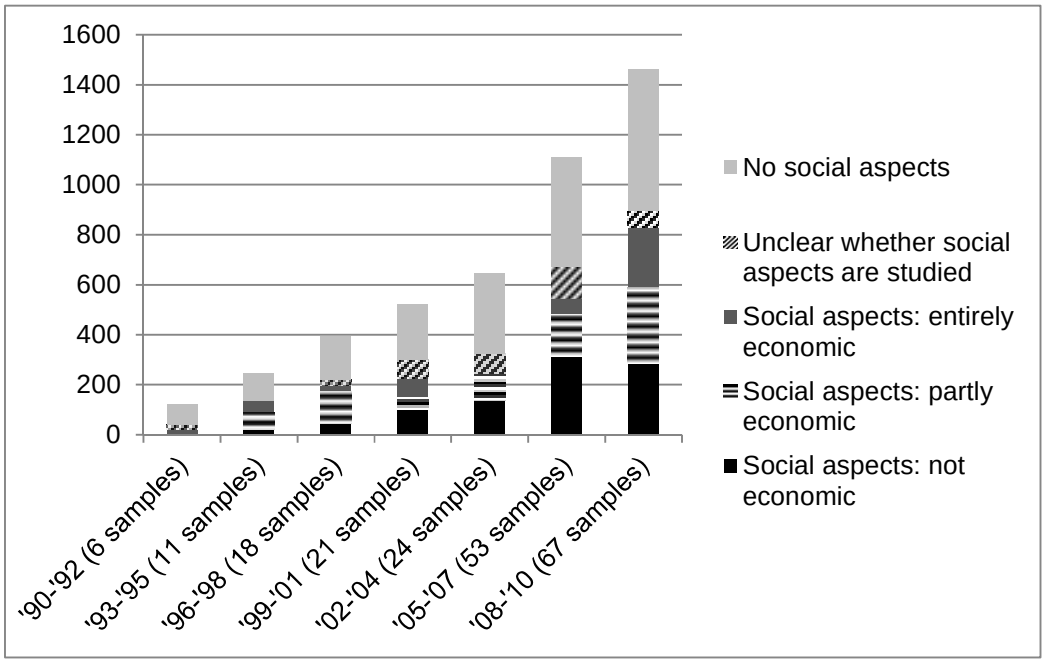


Figure 4: Number of the sampled articles in industrial ecology covering social and economic aspects, normalised to the total number of abstracted articles

5.3. Stable partition of the field

The temporal trends of the shares of 'social IE' articles are studied by making a modification of the above figures on how the articles are categorised regarding if they cover social or economic aspects. The numbers of articles there presented are

transformed to percentage shares for the five sets in three-year groups, as seen in Figure 5.

For all sets except one, the trends are stable or almost stable. The only one that seems to be changing during this time period is the increasing share of the articles represented by the set of articles that cover social but not economic aspects. Stability thus seems to apply to the sets of: no social aspects, unclear whether social aspects are studied, social aspects that are economic, and social aspects that are partly economic. The details for the sets are visualised in Figure 5.

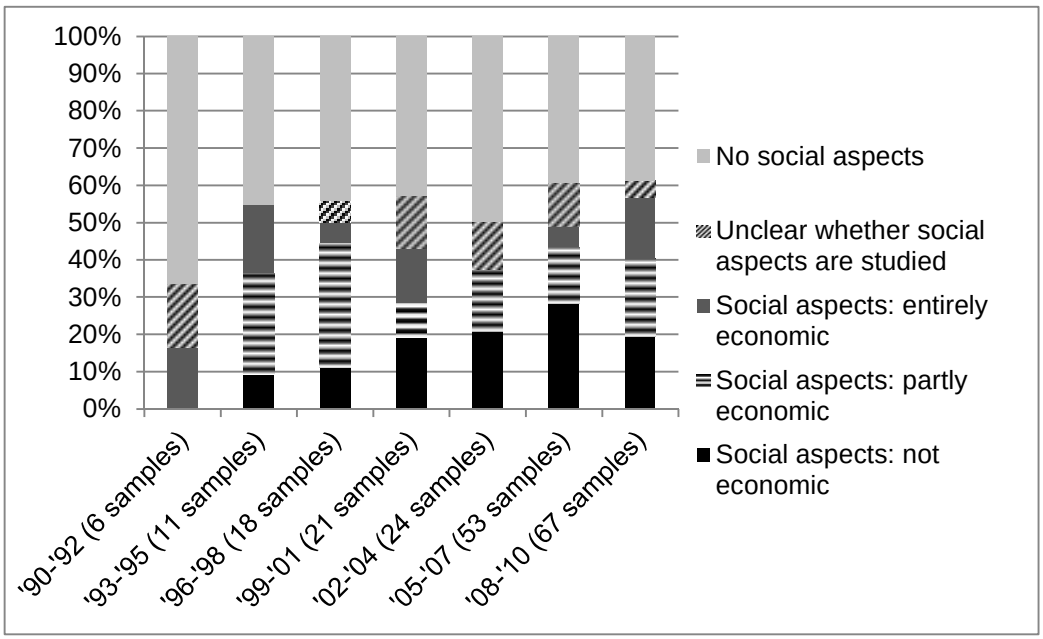


Figure 5: Shares of the sampled articles in industrial ecology covering social and economic aspects, normalised to the total number of abstracted articles

5.4. Examples of social aspects

Here, a few illustrative articles from the sample are briefly presented. This is performed particularly in order to clarify which types of articles that have been organised as covering social aspects in the categorisations carried out. Also, the five more narrow sets that the articles were divided into – no social aspects, unclear whether social aspects are studied, social aspects that are entirely economic, social aspects that are partly economic, and social aspects that are not economic – in the two previous sub chapters, 5.2. and 5.3., are exemplified. Thereby, also the findings from these two sub chapters are further illustrated.

Describing ‘social IE’ through the three articles summarised in this paragraph, cannot, it should first be mentioned, however, result in a fully covering picture. One reason for this is the wide variety of social aspects covered in the field, which was also one of the guiding principles when designing this study. However, even if these three articles were chosen rather to represent the coverage of social aspects than to show their variation, they seem to use clearly different approaches. As a first example, Baumgartner and Zielowski (2007) have compared a concept categorising industry initiatives on zero emission techniques (ZET), to concepts on organisation culture and to sustainable development, respectively. The presented aim is to aid the implementation of ZETs by performing this overview. In a second example, Insa and colleagues (2010), propose the creation of a Spanish national regulation of medical waste handling. They argue that this is important due to differences found in regional Spanish laws on the topic which are mapped and presented in the article. Here, laws, as being tools for explicit control of human behaviour has led to categorising this article as covering social aspects. Finally, in an article by Sharma and colleagues (1997), economic, social and environmental consequences of potential policies for waste paper recycling in Mumbai, India, are assessed. This is performed based on common techniques in the research area environmental economics. Sharma and colleagues present policy recommendations, including a description of why the affected policy contents only are dependent on each other in a few aspects.

As an example of articles categorised as not covering social aspects, a study of chlorine flows by Kleijn and colleagues (1997) is used. They describe a combined substance flow analysis (SFA), LCA, and toxicological risk assessment of chlorinated hydrocarbons (CHCs) in the Netherlands, and commissioned by several Dutch ministries. A calculation of the emissions reductions required by legislations agreed on at the time of their study is included. This article thus covers legislation, but since it is not explicitly evaluated, since no outspoken policy advices are given, and because of the minor focus on legislation in the article, it has not here been categorised as covering social aspects.

The articles where it was unclear whether social aspects were covered or not, are here illustrated by an article on recovery and reuse of industrial cooling water. You and colleagues (1999) describe this topic in Taiwan from several different perspectives. They cover both nationwide characteristics and site specific data. Also, they study technical feasibility for changes as well as mention the influence of operator staff’s experiences for the daily operation of plants. In addition to these operators’ experiences other social factors are more or less touched upon. Taken together, it is unclear whether they represent a considerable part of the research presented in the article. This is partly caused by the many different factors being presented.

The extent of economic aspects covered in the articles where no other social aspects are studied varies, and the example given here represents the articles where economic aspects have a more central role in the article. In the article, Dimitroff-Regatschnig and Schnitzer (1998) present a techno-economic approach for assessing

the difficult task of handling environmental challenges put on companies at the same time as cost efficiency is sought for. They present a more systematic approach than previous ways of linking environmental costs and revenues to economic accounting systems as well as to potential environmental company initiatives.

In order to illustrate the combining of economic and other social aspects, a study on the potential for recycling water in one area in Australia is used. In the study, Hurlimann (2009) presents an overview of the distribution of water in a water scarce area in the region Victoria and a survey of attitudes to for example the price for a hypothetical use of recycled water. The first part describes both technical and economic conditions and suggests further studies of the water cartage industry through a triple bottom line approach or through an LCA. In the survey part, several attitude aspects were studied, but only willingness to pay figures are presented as results. A method, that Hurlimann acknowledge is debated, from environmental economics for estimating willingness to pay was used.

Finally, an example of an article covering social but not economic aspects is given. Meech and colleagues (2006) describe activities for the revitalisation of a contaminated and run-down former mining site in Canada. They describe both future plans and already carried through projects. Environmental and social aspects, such as wellbeing of residents and equity, are presented as being the driving forces. Economic conditions are briefly mentioned but not emphasised and therefore not considered as being clearly covered in this review. The importance of cooperation and the design of the planning process are frequently highlighted but not described further in the article by Meech and colleagues.

5.5. User oriented studies

Below, the types of studies, such as method development or case studies, found among the sampled articles, are presented, describing each of the types separately. All study types initially considered, except theory development, were found among the sampled articles. For an overview of the frequency of the types, see Table 8. The use of two or more different types of studies in one article is further explored in the user oriented section below.

The study of the sampled abstracts lead to the highlighting of the importance of connections between different research projects as a basic condition for the possibilities of furthering connections between IE research and the social sciences, and therefore this is subject to specific attention in the results presentation in this sub chapter.

Table 8: Types of studies in the sampled articles

Type of study	Typical study	Number of sampled articles (200 articles sampled, whereof 41 apply to more than one of the investigated types)	Number of sampled articles only categorized in one of the categories below
		% of the articles	% of the articles
User oriented	Original research, and not clearly requested by or findings not clearly compared to other research	78%	63%
Discussion		12%	4%
Development of research methodology and development of research methods		11%	5%
Reporting, or advertisement		11%	3%
Integrated case	Clearly requested by or findings clearly compared to other research	9%	4%
Editorial of special issue, or conference summary		3%	0%
Synthesis of cases		2%	1%
Review of research		2%	1%
Theory development		0%	0%

User oriented

A majority of the sampled studies were found to be 'user oriented', meaning that the articles are rather focused on for example a commissioner's needs while not being requested by or clearly being used to further other research, as opposed to for example method development and case studies. The user oriented studies are, for example, studies of a technical system or an environmental evaluation of a previously not investigated issue, such as an optimisation of a waste water network using a new approach (Karthick et al. 2010), and as the second hand use of clothes (Farrant et al.

2010), respectively. The studies are often deep and narrow studies that to a considerable degree are based on site and situation specific data, aspects that they share with case studies.

To illustrate the user oriented type of study, the article by Farrant and colleagues (2010), where they describe the properties of a phenomena closely related to previous studies on the environmental impacts of clothes, is used. Despite that several such previous studies have been performed, no citations of the need to study second hand use are made. On the other hand, the problem approach could be labeled as 'quick and creative bottom-up'; the authors have discovered a previously not identified issue, and investigate it immediately. (Farrant et al. 2010)

User oriented studies constitute the entirety of the articles in 63% of the sampled articles. This is the single by far most frequently identified type of study among the types of studies considered; the second most frequent type being discussion articles, found in 12% of the sampled articles, and the second most common study type to cover the whole of an article are the method developments, that account for 5% of the 200 articles, as illustrated in Table 8.

In addition to the above mentioned 63% of the articles, in 15% of the 200 articles, user oriented studies are combined with, for example, method development. This is illustrated by the above mentioned article by Karthick and colleagues (2010), where a study of a petroleum refinery is used to illustrate a new method for water network optimisation. No investigation is made of the usefulness of and opportunities to generalise from this example, and thus the example has more the character of a user oriented study than of an integrated case study, even if the proposed new method is based on a combination of previously established methods.

In some of the articles here categorised as user oriented studies, the authors designate them as case studies, but although the ambitions clearly are presented to be a bridging to previous research, this have not been found to be treated at larger degrees in these articles. For example, Niederl-Schmidinger and Narodoslawsky (2008) call their study a case, but their focus is on the study itself. The stated reasons for carrying it out to fill research gaps while the usefullness of its results to fill these gaps are only shortly mentioned. Niederl-Schmidinger and Narodoslawsky present a comparative environmental assessment study of biodiesel, using the LCA method and with a special focus on aggregating the environmental impact results, but it is not evident that for example, as claimed, their approach makes it easier for engineers to utilise LCA's. (Niederl-Schmidinger and Narodoslawsky 2008)

Integrated cases

The studies that have been labeled as case studies in this review are present in 9% of the sampled articles and constitute the entirety of 4% of the 200 articles, which is also shown in Table 8, and it has been found that these articles are also showing rather few and weak connections to other research although these links are more prominent than

for the user oriented articles. Two main types of case studies can be distinguished: cases used for adding examples to a certain industry sector, such as the case of comparing door panels for evaluation of using LCA as a method for assessing eco-design in the automotive sector (Muñoz et al. 2006), and cases used for furthering method development, such as a study of housing insulation to exemplify a new method for incorporating exposure and risk concepts into life cycle impact assessment (Nishioka et al. 2005). That these both examples are related to LCA also reflects that 47% of the samples identified as, fully or partly, being case studies are published in IJLCA.

Although the cases are more clearly related to other research, the integration of the studies with other studies takes up a relatively small share of their focus, and the comparative study of car door panels by Muñoz and colleagues (2006) is here used to illustrate it. The detailed result description in the article of a comparative LCA is used for deriving a set of eco-design principles while the set is presented without references to examples and without being further discussed and criticised. Also, arguments are drawn from the study itself to explain the authors' conclusion that LCA is very useful for environmental evaluation of the studied car component, such as the discovery of improvement potentials in life cycle phases not expected to be of importance. However, no other articles using the same or other methods or studying other car components, or the lack of such studies, is used to forward the authors claim about the general usefulness of LCA for environmental assessments of car components from an eco-design perspective. (see Muñoz et al. 2006)

Synthesis of cases

In a few sampled articles, amounting to 2% of the 200 articles, different forms of syntheses of cases are made, and where the links between the cases and the syntheses vary in thoroughness. As an example, an introduction to a special issue in JCP on regional sustainability initiatives that include university involvement, draw aggregated conclusions from the other articles of that journal issue (Zilahy et al. 2009). However, the introduction's descriptions of the methods used in and conclusions drawn in the articles of the issue only to a small degree seem to reflect the overall conclusions drawn. For example, the issue articles are said to generally show that outreach activities in academia are not being well appreciated by researchers, but from the individual descriptions of the articles it is unclear in which of the studies that this has been found and how it has been studied. (Zilahy et al. 2009)

Development of research methodology/methods

Some of the sampled articles cover method development, covering instances of both thorough referencing to other research and where no links to other research are presented. In total, 11% of the sampled articles cover method development, while 5% of the 200 articles are in their entirety reporting about method developments. Of the sampled articles identified as covering method development, a large number of them deal with development of method aspects of LCA and 57% of the method

development articles are published in IJLCA. The method development articles cover, for example, scenario methodology using LCA such as the addition of economic and social assessments to the analysis of industrial sectors (Allwood et al. 2008), and exploration of the consequences of importing systems modelling of evolution into IE (Baldwin et al. 2004). The article by Baldwin and colleagues largely contains a review of existing methods, including fields outside of IE. They also present an evolutionary modelling study of primarily employment and location of residential areas in an urban system and draws parallels from it to typical IE systems such as the modelling of flows of metals. The drawing of these parallels is the core of the article, but unclear description of the results and how the parallels were drawn make it difficult for the reader to assess the usefulness of their suggested method development.

Review of research

All three of the 2% of the sampled articles that cover reviews of other research use a life cycle perspective, and an example on transportation in LCAs is here presented. In the study by Jørgensen and colleagues (1996) the contribution from transports in different phases of the methodology and for different products is screened using four other studies. The short article is used for suggesting further research on a few issues indicated by the findings.

Discussions

As an example of the 12% articles categorised as covering discussions more or less, the previously, in sub chapter 5.4, mentioned study by Baumgartner and Zielowski (2007) is here used. It draws preliminary conclusions from a comparison of existing models by discussing ways for companies to work towards sustainability based on a comparison of three existing frameworks, relating to technical, organisational and sustainability aspects, respectively. The discussion is thereby used as a way of quickly and creatively reaching a hypothesis.

Description of a project, etc

The category on description of a project, etc, was found to cover 11% of the articles more or less and is here illustrated by a description of an environmental initiative in industry. The article, by Donnelly and colleagues (2006) lists the contents of and presents the pre-conditions for and the company's perception of an environmental management system created by a company in the mobility communications sector. The ambition with the system is to cover their products' entire lifecycles. Its components, how the relation between these are designed, and responsibility distributions are listed.

Editorials of special issues, or conference summaries

Editorials of special issues and conference summaries, sometimes combined, comprise a special type of articles, since they for the 3% of the sample categorised into this type more or less often cover a range of research that was selected and encouraged with

less control from the author(s) of the together-binding article than for example a review. Here an example that this partly applies to is briefly described. Schneider and colleagues (2010) present and give some further comments to contributions to a special issue based on a conference on economic degrowth. In addition, a definition of the topic is presented and future conditions for degrowth are discussed but not emphasised.

5.6. Sparse use of social theory

In the reviewed articles covering social aspects it is seldom stated clearly that social theory is used and the theories used seem often to be marginally established. Of the articles covering social aspects 4% clearly use theory and 7% clearly or less clearly use it. Two examples are here presented to illustrate the marginality aspect and the unclear cases of whether social theory is used, respectively.

An article by Williams and colleagues (2008) on customer focused design of food-packaging from an LCA and customer perspective is here used to exemplify the use of seemingly marginally established theory. In the article, the effects of packaging on food losses are added to established environmental concerns of packaging. This approach is combined with a ranking and characterisation of technical packaging aspects according to a customer survey performed in another study. In this other study, social theory was used: Kano's theory of attractive quality. The aim of the theory is according to Williams and colleagues (2008) to realise the creating of product qualities that are attractive to consumers, and the name of the theory indicates a narrow range of application. The implications and applicability of the theory is not mentioned in the article.

To illustrate the relatively often occurring situations where it is unclear whether social theory is used or not, an article on the diversity concept by Korhonen (2005) is used. In the article, he presents a continuation of a study on possible contents of a theory of industrial ecology. Both physical flows and organisational components are mentioned, and in most cases these are combined into generalised statements, such as the study of the existence of linkages between different companies. The explicit mentioning of social aspects in the article occurs through short discussions of the implications of not including for example organisation culture aspects in his study.

5.7. Focus on positivism

The social aspects covered in the sampled articles were found to represent two of the four paradigms present in organisation theory according to Hatch (2006). These are the pre-modern and the more complexity focused modernist perspectives, thus representing the positivist and historically earliest appearing stances, while symbolic-interpretative and postmodern perspectives were not present although a very small share of all of the sampled 'social IE' articles tend to go in the direction of a symbolic-interpretative paradigm. Also, the pre-modern perspective is mentioned initially in Hatch's textbook but not considered to be used in the organisation studies field. Thus some overlap but also clear differences regarding perspectives used seem to exist

between IE studies and this research field that they have been attempted to be bridged towards. Below, a few examples are given to show actual forms of these two scientific perspectives found in IE research.

The pre-modern approach is here illustrated by an article by Lee and colleagues (2010) on a decision model for maximizing economic gain in end-of-life management. Their model distinguishes between disposal and remanufacturing for components of products and is fully quantitative. These few and only numerically modelled conditions could be seen as a type within pre-modernist perspectives that is located relatively far from the complexity focussed modernist paradigm.

The complexity focus of the modernist paradigm is here illustrated by a study on precaution regarding nanoparticulate materials by Helland and colleagues (2008). They study several different social aspects, such as exchange of risk information with stakeholders and risk perception in the company, through a text based survey. Thus, the studied aspects form a complex while the method of the study is one-dimensional.

Finally, to exemplify how a few studies seem to go in the direction of the symbolic paradigm but not very far an article by Wilson and Williams (2007) on for example perception discrepancies is used. They study the differences between authorities peoples' and the public's indicators for evaluating a recycling system. However, the authors suggest that the topic should be further studied using opinion surveys, which leads it more towards the modernist paradigm rather than what a more in depth analysis would have made possible.

5.8. Identified concepts on social aspects within industrial ecology

Concepts on social aspects identified in the journal articles here reviewed are described in this subchapter. In total 24 concepts or concept groupings were found, and they mainly cover management and economy aspects from a business perspective while also a few concepts on policy, education and social responsibility were identified (see Table 9 for a full listing of these concepts).

Table 9: Concepts on social aspects within industrial ecology

Concept(s)	Number of abstracted articles identified
Agent-based modelling & simulation	7
Business strategy	11
Cost-benefit analysis	27
Decoupling	11
Degrowth	4
Dematerialize	21
Education	158
(Extended) producer responsibility	29
Flow accounting	7
Human resources	12
Industrial symbiosis & eco-industrial parks	74
Input-output (economic modelling)	110
Institutional theory & capacity	8
Integrated management system	8
Integrated product policy	7
ISO 14xxx & EMAS (standards for environmental management)	50
Life cycle costs	52
Life cycle management	32
Life cycle thinking	28
Management accounting	10
Microeconomy & macroeconomy	16
Social life cycle assessment	16
Supply chain management	31
Technological change & innovation system, studies & theory	27

Four of these concepts were considered to be more central to the field, and thereby have been treated as proxies of 'social IE' sub areas, and each of these are identified in between 52 and 16 articles – life cycle cost(s)/costing (LCC), life cycle management (LCM), supply chain management (SCM) and associated terms, and social/societal life cycle assessment (SLCA). These proxy areas are generally introduced in the first subsequent part of this subchapter. Then, nine potentially central social concepts identified are briefly reviewed.

Of the four proxy areas, three are found in all of the five journals reviewed, as illustrated in Table 10. The exception is SLCA, found almost only in IJLCA. Thus, a major part of the research relating to these proxy fields seems to be spread throughout IE research and not limited to one or a few journals.

Table 10: Number of articles on the four proxy sub fields in each journal

	Journal of Industrial Ecology	Progress in Industrial Ecology	International Journal of Life Cycle Assessment	Journal of Cleaner Production	Resources, Conservation & Conservation	**Total**
Life cycle costs	7	1	25	11	8	**52**
Life cycle management	6	5	9	11	1	**32**
Supply chain management	2	2	2	23	2	**31**
Social life cycle assessment	1		15			**16**

Life cycle cost(s) and life cycle costing

LCC is mainly used as a method for calculating costs along the entire product life cycle, or along a large part of it (see e.g. Klöpffer 2008), and besides differences in its coverage also the aims of using it vary to some extent. According to Hunkeler and Rebitzer's experience of LCM discussions LCC is "an essential link for connecting environmental concerns with core business strategies" (Hunkeler and Rebitzer 2003:109). LCC is, by Höjer and colleagues (2008), presented as an analytical tool for analysing environmental impacts along for example LCA and cost-benefit analysis (CBA). Additionally, in two anthologies published by the, to LCA and IE research relatively closely connected, toxicological research society SETAC, further definitions of LCC for environmental and societal assessments are put forward (see Hunkeler et al 2008 and Swarr et al 2011b).

Regarding the origin of LCC, different focuses are also presented. The executive summary of the first of the SETAC anthologies on LCC mentioned above claims that "[c]onventional life cycle costing (LCC) is, to a large extent, the historic and current practice in many governments and firms" (Hunkeler et al 2008:xxvii). On the other hand, in an article briefly presenting the second anthology mentioned earlier, the authors claim that important foundations of LCC come from systems engineering and also put forward that LCC predates LCA (Swarr et al 2011a).

LCC has become established in Industrial Ecology, based on the articles on LCC that were screened. This is shown by, for example, the straightforward use of the term LCC in most of the recent paper titles, such as "Life cycle cost disclosure, consumer behavior, and business implications" (Deutsch 2010). Also, even if almost half of the number of the 52 articles on LCC identified were published in IJLCA, at least seven articles were found in each of the journals JIE, JCP and RCR.

Finally, a topical editor exists in IJLCA on environmental LCC, as of 13 April 2012.

Over the years a partial shift seems to have occurred from articles discussing the definition of LCC and the value of using it, to direct applications of the concept. For example, it was used in one relatively recent study for comparing the LCC in the whole product life cycles under hypothetical compliance and pollution prevention strategies, respectively, regarding the entire cycles costs, for ten examples (Krozer 2008). It is partly unclear how large parts of the product life cycles that were covered in the study and whom the calculated costs affect. The cost calculations of the study compare the costs for conventional emissions reduction technologies to innovative changes, which to some degree is emphasised. Regarding broader aspects studied in the earlier years, LCC was for example covered concerning its importance as, amongst others, the economic pillar of sustainability in product development (Klöppfer 2003). The article discusses product life cycle related assessments of the environment, economy, and social issues, and LCC is presented as one term for the economic counterpart of LCA. The scope of the coverage of costs is discussed, partly clarifying and specifying the origins of these costs, and the potential double counting when combining LCC and LCA is mentioned.

Life cycle management

LCM has besides being a term used in the five journals here reviewed been the term labelling an international conference launched in 2001, but its definitions diverge. At the first of these conferences, two partly different definitions were presented. Franklin and colleagues (2001) differentiated LCM from LCA, claiming that the former does not cover the entire product life cycle and all environmental issues, but chooses these based on law compliance, business goals, and practical feasibility to influence them. To a lesser degree than Franklin, Weidema (2001) points to differences between LCM and LCA, describing LCM as being inspired by LCA and covering the whole product life cycle.

Also, and which is apparent from the description in the previous paragraph, the above cited conference contributions present diverging origins of the concept. According to Franklin (2001), LCM was developed by the automotive company DaimlerChrystler to balance their costs. This differs from the origin in LCA presented by Weidema (2001).

The 32 articles on LCM identified are most clearly established in the field through topical editors on the subject in the journals JIE and IJLCA. In an introduction to the topical coverage in IJLCA, LCM was put forward as mainly covering actual use of and education on LCA and life cycle thinking (LCT) (Heinrich and Klöpffer 2002).

The use of the term LCM in IE research covers both applications and method development. The applications are made of specific industry sectors as well as at a level covering large parts of society. Some of the applications are only explicitly related to LCM by descriptions of the need of these studies for carrying out LCM well, which is the case for an MFA based on economic input-output (IO) data of polyvinyl chlorides (PVC) in Japan (Nakamura et al 2009). The article points out the importance

of waste separation of PVC products for successful LCM of PVCs and explains the features and of the combined method used. Regarding the method development articles, the degree to which these specifically relate to LCM varies. One example of partly relating the article to the concept is an outlining of a way to reach a holistic LCM approach in the manufacturing industry (Brent 2005). The article refers to, but do not emphasise, LCM as an extension of life cycle engineering's (LCE) evaluation of environmental effects from different design options of a product, process or service to include management beyond the design phase. South African experiences of inefficient decision utilisation of environmental consequences highlighted by LCAs and LCM are used as a starting point. To handle this issue, a combining of the environmental, economic and social influences from the life cycles of projects, assets and products is proposed and outlined.

Supply chain management

SCM is, according to a screening performed during this review, mainly studied via several associated concepts of it in IE (see e.g. Seuring 2004 and Nawrocka et al 2009), for example environmental supply chain management (ESCM), and therefore the starting point here is to review definitions both of SCM and of the repeatedly occurring associated concepts. According to for example Mentzer and colleagues (2001) the already in 2001 well established term SCM had been used in different ways. In the article they claim that the term supply chain is more agreed upon, as the upstream and downstream flows – involving three or more entities such as companies – of products, services, finances and information. The definitions of SCM are in their article organised either as a management philosophy perspective denoted supply chain orientation (SCO), or as practical management activities or processes containing a set of activities. Turning to the two scientific journals that contain SCM in their titles, the high impact Journal of Supply Chain Management (JSCM), impact factor 5.853 as of 4 April 2012, highlights the forwarding and presence of an SCM theory while not specifying its study objects (Wiley 2012). Supply Chain Management, An International Journal covers the relation of supply chain operation to a wide range of topics, including marketing, logistics and organisational behaviour (Emerald 2012).

Out of seven identified associated terms of SCM, four have been attempted to be compared to each other and to a few other concepts by Seuring (2004). The three not covered are: closed-loop supply chain management (see Seitz 2007), product chain management (see Boons 2002) and supply chain environmental management (see Gamage et al 2008), used in each one of the abstracted articles found on SCM in the five journals. Seuring (2004) treats ESCM, green supply chain management (GSCM) and sustainable supply chain management (SSCM) as one entity, and as targeting problems similar to those handled through 'normal' SCM. An emphasis on operational execution is presented as a characteristic, regarding for example whether implementation of environmental and social goals in the company or supply chain will conflict with economic goals. Integrated Chain

Management (ICM) is described as using a material and energy flows approach combined with a focus on a wider scope of stakeholders', for example governments and NGOs, pressures regarding environmental and social issues.

Regarding the origin of SCM the differing focuses of the two journals cited in the previous paragraph is here used. JSCM clearly states its perspective by confining its contents to behavioural research (Wiley 2012). On the other hand, Supply Chain Management, An International Journal emphasises practical management opportunities and problems such as efficient consumer responses. Thus, SCM seems to have roots in both academia and in business practices, which is supported by Mentzer and colleagues (2001) who base their synthesising of the term SCM on definitions from both of these two domains.

Different bases for the SCM associated concepts have also been found. The use of the terms ESCM and ICM have been identified in both the five journals in focus in this study and in business and management journals, according to a Scopus search as of 4 April 2012. In line with this, Seuring (2004) places the origin of the by researchers not frequently used term ICM in public policy in The Netherlands and Germany dating back to the late 1980's, and in imports of existing LCA knowledge. Particularly GSCM, but also SSCM, were found in a considerably larger number of articles and mainly in research on business and management, as of a Scopus search on 4 April 2012.

In addition to the 30 abstracted articles identified on SCM and its associated terms in the five journals, the terms seem to be established in the field based on two topical editors on SCM in JIE and one on sustainability and SCM in JCP, as of 13 April 2012, and considering the recurring use of the sub terms of SCM. If ESCM and GSCM are grouped together similarly to Seuring's (2004) categorisation, 12 abstracted articles are covered in the five journals.

Of the five journals, SCM and its associated terms are mostly found in JCP, and an overall trend towards establishing the concepts is seen since the first use of any of them in an abstracted article in one of the five here reviewed journals occurred in 2000. As an early example of the use of the term SCM, a study by Backhouse and colleagues (2004) comparing potentially important future metal casting materials and recycling rates is here referred to. In the article, SCM is described regarding and seen as relevant for for example environmental and employee empowerment reasons. The use of SCM for the results of the study, which are quantified through an LCA approach, lies in an indirect application of different recycling rates. A later and less novel state of the study of SCM is illustrated by an article on practices of using the environmental management system ISO 14001 in Swedish companies, by Nawrocka and colleagues (2009). The article presents a combined methodology – of interviews, focus groups and questionnaires – for expanding the knowledge on the role of ISO 14001 for ESCM. Communication facilitation and problems of the standard between customer and supplier are found to be relevant topics but they are not emphasised by the article. Conclusions are in the article drawn from external factors not directly studied, such as environmental ambitions of suppliers.

Social/societal life cycle assessment

A distinct difference in the use of the term SLCA can be seen. SLCA is generally referred to as an evaluation method similar to environmental LCA (usually denoted LCA), but where social instead of environmental effects from activities along product life cycles are studied – such as regarding child labour and corruption (see e.g. Dreyer et al 2008, Hunkeler 2006, Jørgensen et al 2008, and Benoît et al 2010). However, the earliest published article found on SCLA in the five journals introduces the term as representing social effects onto the product life cycle, such as decision-making structure and promotion/blocking of technical and planning developments (see O'Brien et al 1996). The article by O'Brien and colleagues (2006) is also cited in three out of four articles previously in this paragraph identified as particularly focusing on defining SLCA methodology (see Dreyer et al 2008, Hunkeler 2006, Jørgensen et al 2008, and Benoît et al 2010).

Following the currently general view on SLCA as being an assessment of social effects from product life cycles, its origin is mainly a translation of LCA to cover also the effects on the social, which often is seen as one out of three pillars of sustainability (see Dreyer et al 2006, Hunkeler 2006, Klöpffer 2008). This includes the outlining of a method for combining LCA, LCC and SLCA into life cycle sustainability assessments (LCSA) (see e.g. Klöpffer 2008). This origin thus more comes from different concepts than from practice, and this is emphasised by an article by Jørgensen and colleagues (2009), where they for example find that companies often see their social responsibility as being larger than the range covered by the SLCA methodology.

SLCA is established through for example a topical editor in IJLCA, but is the smallest, latest established, and most to one journal limited of the four proxy sub areas of 'social IE' identified in the five journals. Sixteen abstracted SLCA articles were found, compared to between 31 and 52 for each of the other proxy areas. Regarding the age of the proxy area, only two articles were published before the year 2006. Finally, 93% of the articles are published in IJLCA, while between 34% and 74% of the articles of the other proxy areas are published in their respective main journal.

SLCA has in the five journals mainly been studied regarding SLCA methods, evaluations of others' SLCA methods, and for the encouragement of using SLCA. As an example of a suggested method, a study by Hunkeler (2006) is here used. In the article, he uses employment hours per environmental impact along the product life cycle in order to have one measure that can be aggregated instead of the several hundreds of diverse social impacts from product life cycles suggested by others. Impact categories, such as housing possible to buy from income from these hours are then calculated. Also, an example using two detergents is presented in the article. An article by Jørgensen and colleagues (2010) on impact categories in SLCA has been chosen to illustrate method analysis and discussion in a later stage of the proxy area's trajectory, where focus lies on parts of SLCA rather than the entire concept. In the article, the aspects assessed in SLCA, and the indicator

incidence of child labour, respectively, are studied. As the aspects assessed, the relevance of and feasibility of assessing human well-being, and particularly the, at the time of the study not in SLCA covered, subjective well-being are studied. Regarding child labour, the scientific knowledge on and stakeholder requests regarding effects of this phenomenon are covered.

Additional concepts on social aspects in industrial ecology

Besides the above described 'social IE' proxy areas, a number of potentially central, of possibly relevant, and of marginally used, respectively, concepts on social aspects were identified in this review.

Nine potentially central concepts were found, which have a few but not as many characteristics of an established concept as LCC, LCM, SCM or SLCA, and they are listed in Table 11. Of these concepts, the number of abstracted articles they were identified in ranges from 60-200 for three of them: education, input-output (IO) which is an economic modelling, and industrial symbiosis (IS) and eco-industrial parks (EIP). It ranges from 20-59 for four of them: ISO 14xxx and EMAS which are environmental management standards, extended producer responsibility (EPR) and producer responsibility, cost-benefit analysis (CBA), and dematerialisation. Thirdly, it ranges from 10-19 for two of them: human resources and decoupling. All of these nine article collections cover method development in relation to the concept in question but to a lesser degree than for the four proxy sub areas. Additionally, they are in some cases mostly only studied explicitly in smaller parts of the articles, particularly regarding IO but also for example CBA. Also, for some of the concepts it is not clear when social aspects actually are covered, such as for IS and EIP, and for some of the concepts many different social aspects are studied in different articles but not related to each other, particularly regarding education.

Table 11: Potentially central concepts on social aspects in industrial ecology

Concept	Number of abstracted articles identified
Cost-benefit analysis	27
Decoupling	11
Dematerialize	21
Education	158
(Extended) producer responsibility	29
Human resources	12
Industrial symbiosis & eco-industrial parks	74
Input-output (economic modeling)	110
ISO 14xxx & EMAS (standards for environmental management)	50

In addition to the nine potentially central concepts, five possibly relevant concepts and *six* marginally used concepts were identified. All of these show a small tendency towards method development related to a certain concept but are even more fragmented than the potentially central concepts mentioned in the previous paragraph. Examples of possibly relevant concepts are life cycle thinking (LCT) and technological change, while degrowth is one of the marginally used concepts here identified as occurring in between four and nine abstracted articles.

6. Discussion

In this chapter a few reflection are made upon the time span covered, the usefulness of the abstract studies, possible alternative or further studies on the issue, and a broader outlook that is inspired by these reflections and the findings of this study.

Firstly, the results and the analysis findings in this study seem to be well in line with the period following the years that this study is based on, 2011-March 2014, judging from our reading of tables of contents of the five journals during this latter period of time.

Second, this review is to a large extent based on the study of article abstracts, and therefore the relation between the abstracts and their full-texts is central for the feasibility of this study and will be described here. Initial screenings of abstracts and corresponding full-texts established both an understanding of the field and the possible explanations that could be found to the research problem identified. At the same time, the full-texts were found to relatively well reflect their abstracts. The later systematic study of the abstracts resulted in a substantial but not large part of the categorisations attempted to be carried out to be ambiguous. This was found to be reflected in the articles when some of these where read more thoroughly as examples of the preliminary findings. Also, the sometimes not clear, amongst others, purposes and methods referred to in abstracts and full-texts could be seen as related to the finding that the majority of the articles reviewed were identified as user oriented studies and thereby not having a large or a clearly defined audience in the community.

Further, in the research here studied, the scholars have covered a diverse array of methods and approaches to social aspects. Therefore, it would be very difficult for a researcher to be familiar with all of the here reviewed articles, and consequently the interpretations most probably will differ depending on who undertakes a study similar to this study. On the other hand, the relatively clear and not too complex or technical language used in the articles and the abstracts, seem to aid other researchers to evaluate the reasonableness of the results and conclusions put forward in this study.

Regarding possible other approaches close to the study in this report, further close studies are here reflected upon. If changes of how ‘social IE’ research is performed are requested, a deeper analysis could provide further ideas for whether and potentially how such changes could occur. Since this study has indicated a relative homogeneity regarding for example paradigms and study types utilised in ‘social IE’ studies, it might be possible to find representative examples researchers to study although a multitude of different social aspects are covered in the field. Either interviews or observations, or both could be used as methods for carrying this through. However, since the findings presented in this study cover practices that has been largely in place for longer time periods at least a certain level of inertia could be expected to exist. Thereby a furthered close analysis may on the other hand give false expectations.

Based on the seemingly loosely held together research reviewed in this study, and the limitations of the alternative or further studies discussed in the above paragraph, much wider and different approaches might be relevant. The little progress of ‘social IE’ studies might be logically understood through seeing its place in society as a whole. IE researchers might have a not much handled role of exploring social aspects without much training for or possibility of communicating this knowledge. It may be useful to explore how such roles are constructed and related to society as a whole. This could reveal overarching driving forces and the from the research perspective user oriented looking behaviours as strongly held together but impacting other parts of society in various ways. Also, it might be too difficult to integrate the already complex knowledge of the many environmental impacts and technical systems in industry to social aspects in a systematic way.

7. Conclusions

This study set out by searching explanations for the discrepancy between the repeated calls for and presented opportunities of and the slow progress in ‘social IE’ studies. This was performed through an explorative review of articles in five journals in the field. Some unclear contents of abstracts and full-texts studied have been discussed in the previous chapter but seem not to affect the relevance of the findings pointed out in the Results and Analysis chapters. Also, limitations in the scope, particularly regarding not studying the subject from a holistic approach of society at large, of this study were pointed out in the Discussion chapter. These reflections could also be seen as results of this study and pointing towards possible future approaches.

The findings from this study that these conclusions mainly are based on are several and are listed here. The number of articles published has been growing rapidly since the first of the journals was launched, in 1988. JCP and PIE have the highest shares of ‘social’ articles within each of the journals. A large number of the studies cover social aspects, whereof economic aspects account for a large part. For both the studies on social aspects in general and on economic aspects, the absolute number of articles has increased over the years while their shares of the field have remained stable. Analysing the whole field, the articles often seem to be user oriented, which importantly includes that they seem to make little explicit use of and are little explicitly designed to contribute to other research. Also, when looking closer at the social articles, it is revealed that only a small part of the social aspects are researched using social theory, and then often using marginally known theories. Also, no or very few of the studies on social aspects align to any of the paradigms that represent a large part of the social sciences during the last half century. Finally, from a survey of proxy sub fields of ‘social IE’, four rather small groupings are identified: life cycle costs, life cycle management, supply chain management with several associated concepts, and social life cycle assessment.

References

Allwood, J. M., S. E. Laursen, S. N. Russell, C. M. de Rodríguez, and N. M. P. Bocken (2008) An approach to scenario analysis of the sustainability of an industrial sector applied to clothing and textiles in the UK. *Journal of Cleaner Production 16*(12): 1234-1246.

Backhouse, C. J., A. J. Clegg, and T. Staikos (2004) Reducing the environmental impacts of metal castings through life-cycle management. *Progress in Industrial Ecology 1*(1-3): 271-285.

Baldwin, J. S., K. Ridgway, B. Winder, and R. Murray (2004) Modelling industrial ecosystems and the "problem" of evolution. *Progress in Industrial Ecology 1*(1-3): 39-60.

Bauman, Z. and T. May (2004) *Att tänka sociologiskt: Andra omarbetade upplagan*. [Thinking sociologically: Second revised edition]. Gothenburg, Sweden: Bokförlaget Korpen.

Baumann, H. (2009) Don't fence me in ... In *The social embeddedness of industrial ecology*, edited by F. Boons and J. Grenville-Howard. Cheltenham, MA: Edward Elgar.

Baumann, H., F. Boons, and A. Bragd (2002) Mapping the green product development field: Engineering, policy and business perspectives. *Journal of Cleaner Production 10*(5): 409–425.

Baumgartner, R. J. and C. Zielowski (2007) Analyzing zero emission strategies regarding impact on organizational culture and contribution to sustainable development. *Journal of Cleaner Production 15*(13-14): 1321-1327.

Benoît, C., G. A. Norris, S. Valdivia, A. Ciroth, A. Moberg, U. Bos, et al (2010) The guidelines for social life cycle assessment of products: Just in time! *International Journal of Life Cycle Assessment 15*(2): 156-163.

Boons, F. (2002) Greening products: A framework for product chain management. *Journal of Cleaner Production 10*(5): 495-505.

Boons, F. and J. Grenville-Howard, (eds) (2009) *The social embeddedness of industrial ecology*. Cheltenham, MA: Edward Elgar.

Brent, A. C. (2005) The application of life cycle management in decision making for sustainable development at government and corporate level: the integration of project, asset and product life cycles. *Progress in Industrial Ecology 2*(2): 223-235.

Brunklaus, B. (2010) *Social dimensions in industrial ecology research – a literature study*. Unpublished working paper, Environmental Systems Analysis, Chalmers University of Technology, Gothenburg, Sweden.

Deutsch, M. (2010) Life Cycle cost disclosure, consumer behavior, and business implications. *Journal of Industrial Ecology 14*(1): 103-120.

Dimitroff-Regatschnig, H. and H. Schnitzer (1998) A techno-economic approach to link waste minimization technologies with the reduction of corporate

environmental costs: Effects on the resource and energy efficiency of production. *Journal of Cleaner Production 6*(3-4): 213-225.

Donnelly, K., Z. Beckett-Furnell, S. Traeger, T. Okrasinski, and S. Holman (2006) Eco-design implemented through a product-based environmental management system. *Journal of Cleaner Production 14*(15-16): 1357-1367.

Dreyer, L. C., M. Z. Hauschild, and J. Schierbeck (2006) A framework for social life cycle impact assessment. *International Journal of Life Cycle Assessment 11*(2): 88-97.

Ehrenfeld, J. 2009. A critical view on the social science contribution to industrial ecology. In *The social embeddedness of industrial ecology*, edited by F. Boons and J. Grenville-Howard. Cheltenham, MA: Edwar Elgar.

Emerald (2012) *Supply Chain Management, An International Journal - About the journal*. Retrieved 4 Apr 2012, from http://www.emeraldinsight.com/products/journals/journals.htm?id=scm.

ES&T (2012) *Environmental Science & Technology – About the journal*. http://pubs.acs.org/page/esthag/about.html. Accessed 8 Mar 2012.

Farrant, L., S. I. Olsen, and A. Wangel (2010) Environmental benefits from reusing clothes. *International Journal of Life Cycle Assessment 15*(7): 726-736.

Franklin, W. E., B. J. Sauer, S. G. Yester, M. Binder, and M. Finkbeiner (2001) Using life cycle assessment and life cycle management to support more informed business decisions. *1st International Conference on Life Cycle Management*. Copenhagen, 27-29 August 2001.

Gamage, G B, C. Boyle, S. J. McLaren, and J. McLaren (2008) Life cycle assessment of commercial furniture: A case study of Formway LIFE chair. *International Journal of Life Cycle Assessment 13*(5): 401-411.

Glaser, B. and A. Strauss (2006) *The discovery of grounded theory: Strategies for qualitative research*. New Brunswick, NJ: Aldine Transaction.

Hatch, M. J. (2006) *Organization theory: Modern, symbolic, and postmodern perspectives: Second edition*. Oxford: Oxford University Press.

Heinrich, A. B. and W. Klöpffer (2002) Editorial: LCM - Integrating a new section in Int J LCA. *International Journal of Life Cycle Assessment 7*(6): 315-316.

Helland, A., H. Kastenholz, and M. Siegrist (2008) Precaution in practice: Perceptions, procedures, and performance in the Nanotech Industry. *Journal of Industrial Ecology 12*(3): 449-458.

Höjer, M., S. Ahlroth, K. H. Dreborg, T. Ekvall, G. Finnveden, O. Hjelm, et al (2008) Scenarios in selected tools for environmental systems analysis. *Journal of Cleaner Production 16*(18): 1958-1970.

Hunkeler, D. (2006) Societal LCA methodology and case study. *International Journal of Life Cycle Assessment 11*(6): 371-382.

Hunkeler, D., K. Lichtenvort, G. Rebitzer, and A. Ciroth (2008) *Environmental life cycle costing*. Pensacola, FL: SETAC.

Hunkeler, D. and G. Rebitzer (2003) Life cycle costing - Paving the road to sustainable development? *International Journal of Life Cycle Assessment 8*(2): 109-110.

Hurlimann, A. C. (2009) Water supply in regional Victoria Australia: A review of the water cartage industry and willingness to pay for recycled water. *Resources, Conservation & Recycling 53*(5): 262-268.

IJLCA (2011) *International Journal of Life Cycle Assessment – About this journal*. http://www.springer.com/environment/journal/11367. Accessed 5 May 2011.

Insa, E., M. Zamorano, and R. López (2010) Critical review of medical waste legislation in Spain. *Resources, Conservation & Recycling 54*(12): 1048-1059.

ISIE (2012) *About the International Society for Industrial Ecology*. http://www.is4ie.org/about. Accessed 1 Mar 2012.

JCP (2010) *Journal of Cleaner Production*. http://www.elsevier.com/wps/find/journaldescription.cws_home/30440/description#description. Accessed 6 Oct 2010.

JIE (2010) *Journal of Industrial Ecology – Overview*. http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1530-9290/homepage/ProductInformation.html. Accessed 6 Oct 2010.

Jørgensen, A., M. Z. Hauschild, M. S. Jørgensen, and A. Wangel (2009) Relevance and feasibility of social life cycle assessment from a company perspective. *International Journal of Life Cycle Assessment 14*(3): 204-214.

Jørgensen, A., L. C. H. Lai, and M. Z. Hauschild (2010) Assessing the validity of impact pathways for child labour and well-being in social life cycle assessment. *International Journal of Life Cycle Assessment 15*(1): 5-16.

Jørgensen, A., A. Le Bocq, L. Nazarkina, and M. Hauschild (2008) Methodologies for social life cycle assessment. *International Journal of Life Cycle Assessment 13*(2): 96-103.

Jørgensen, A. M., P. E. Ywema, N. Frees, S. Exner, and R. Bracke (1996) Transportation in LCA: A comparative evaluation of the importance of transport in four LCAs. *International Journal of Life Cycle Assessment 1*(4): 218-220.

Kallio, T. and P. Nordberg (2006) The evolution of organizations and natural environment discourse: Some critical remarks. *Organization & Environment 19*(4): 439-457.

Karthick, R., G. Kumaraprasad, and B. Sruti (2010) Hybrid optimization approach for water allocation and mass exchange network. *Resources, Conservation & Recycling 54*(11): 783-792.

Kleijn, R., A. Tukker, and E. van der Voet (1997) Chlorine in the Netherlands, part I, an overview. *Journal of Industrial Ecology 1*(1): 95-116.

Klöpffer, W. (2003) Life-cycle based methods for sustainable product development. *International Journal of Life Cycle Assessment 8*(3): 157-159.

Klöpffer, W. (2008) Life cycle sustainability assessment of products (with Comments by Helias A. Udo de Haes, p. 95). *International Journal of Life Cycle Assessment 13*(2): 89-94.

Korhonen, J. and P. Strachan (2004) Editorial: Towards progress in industrial ecology. *Progress in Industrial Ecology 1*(1/2/3): 1-23.

Korhonen, J. (2005) Theory of industrial ecology: the case of the concept of diversity. *Progress in Industrial Ecology 2*(1): 35-72.

Kronenberg, J. (2006) Industrial ecology and ecological economics. *Progress in Industrial Ecology 3*(1-2): 95-113.

Krozer, Y. (2008) Life cycle costing for innovations in product chains. *Journal of Cleaner Production 16*(3): 310-321.

Lee, H. B., N. W. Cho, and Y. S. Hong (2010) A hierarchical end-of-life decision model for determining the economic levels of remanufacturing and disassembly under environmental regulations. *Journal of Cleaner Production 18*(13): 1276-1283.

Meech, J. A., M. McPhie, K. Clausen, Y. Simpson, B. Lang, E. Campbell, et al (2006) Transformation of a derelict mine site into a sustainable community: The Britannia project. *Journal of Cleaner Production 14*(3-4): 349-365.

Mentzer, J. T., W. DeWitt, J. S. Keebler, S. Min, N. W. Nix, C. D. Smith, et al (2001) Defining supply chain management. *Journal of Business Logistics 22*(2): 1-26.

Muñoz, I., J. Rieradevall, X. Domènech, and C. Gazulla (2006) Using LCA to assess eco-design in the automotive sector: Case study of a polyolefinic door panel. *International Journal of Life Cycle Assessment 11*(5): 323-334.

Nakamura, S., K. Nakajima, Y. Yoshizawa, K. Matsubae-Yokoyama, and T. Nagasaka (2009) Analyzing polyvinyl chloride in Japan with The waste input-output material flow analysis model. *Journal of Industrial Ecology 13*(5): 706-717.

Nawrocka, D., T. Brorson, and T. Lindhqvist (2009) ISO 14001 in environmental supply chain practices. *Journal of Cleaner Production 17*(16): 1435-1443.

Niederl-Schmidinger, A. and M. Narodoslawsky (2008) Life cycle assessment as an engineer's tool? *Journal of Cleaner Production 16*(2): 245-252.

Nishioka, Y., J. I. Levy, G. A. Norris, D. H. Bennett, and J. D. Spengler (2005) A risk-based approach to health impact assessment for input-output analysis: Part 2: Case study of insulation. *International Journal of Life Cycle Assessment 10*(4): 255-262.

O'Brien, M., A. Doig, and R. Clift (1996) Social and environmental life cycle assessment (SELCA): Approach and methodological development. *International Journal of Life Cycle Assessment 1*(4): 231-237.

OED Online (2012a) social, adj. and n. Oxford University Press. http://www.oed.com/view/Entry/183739. Accessed 23 Oct 2012.

OED Online (2012b) social science, n. Oxford University Press. http://www.oed.com/view/Entry/183756. Accessed 11 Feb 2013.

Piasecki, B. (1992) Industrial ecology: An emerging management science. In *Proceedings of the National Academy of Sciences USA, Vol. 89*. Washington, DC: National Academy of Sciences.

PIE (2011) *Progress in Industrial Ecology, An International Journal*. http://www.inderscience.com/browse/index.php?journalID=55. Accessed 10 May 2011.

RCR (2010) *Resources, Conservation and Recycling – Aims and scope*. http://www.journals.elsevier.com/resources-conservation-and-recycling/#description. Accessed 6 Oct 2010.

Schneider, F., G. Kallis, and J. Martinez-Alier (2010) Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. *Journal of Cleaner Production 18*(6): 511-518.

Seitz, M. A. (2007) A critical assessment of motives for product recovery: the case of engine remanufacturing. *Journal of Cleaner Production 15*(11-12): 1147-1157.

Seuring, S. (2004) Industrial ecology, life cycles, supply chains: Differences and interrelations. *Business Strategy and the Environment 13*(5): 306-319.

Sharma, V. K., P. van Beukering, and B. Nag (1997) Environmental and economic policy analysis of waste paper trade and recycling in India. *Resources, Conservation & Recycling 21*(1): 55-70.

Silverman, D. (2006) *Interpreting qualitative data: Methods for analyzing talk, text and interaction. 3 ed*. London: Sage Publications.

Swarr, T. E., D. Hunkeler, W. Klöpffer, H.-L. Pesonen, A. Ciroth, A. C. Brent, et al (2011a) Environmental life-cycle costing: a code of practice. *International Journal of Life Cycle Assessment 16*(5): 389-391.

Swarr, T. E., D. Hunkeler, W. Klopffer, H.-L. Pesonen, A. Ciroth, A. C. Brent, et al, Eds. (2011b) *Environmental life cycle costing: A code of practice*. Pensacola, FL: SETAC.

Weidema, B. (2001) LCM - A synthesis of modern management theories. *1st International Conference on Life Cycle Management*. Copenhagen: 27-29 August 2001.

Wiley (2012) *Journal of Supply Chain Management - Overview*. Retrieved 4 Apr 2012, from http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291745-493X/homepage/ProductInformation.html.

Williams, H., F. Wikström, and M. Löfgren (2008) A life cycle perspective on environmental effects of customer focused packaging development. *Journal of Cleaner Production 16*(7): 853-859.

Wilson, C. D. H. and I. D. Williams (2007) Kerbside collection: A case study from the north-west of England. *Resources, Conservation & Recycling 52*(2): 381-394.

Yin, R. (2009) *Case study research: Design and methods: Fourth edition*. Los Angeles: Sage.

You, S. H., D. H. Tseng, G. L. Guo, and J. J. Yang (1999) The potential for the recovery and reuse of cooling water in Taiwan. *Resources, Conservation & Recycling 26*(1): 53-70.

Zilahy, G., D. Huisingh, M. Melanen, V. D. Phillips, and J. Sheffy (2009) Roles of academia in regional sustainability initiatives: outreach for a more sustainable future. *Journal of Cleaner Production 17*(12): 1053-1056.

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Appendix

Table A.1: References for the 200 randomly sampled articles

#	Reference*
1	Abd El-Salam, M. M. & H. M. El-Naggar (2010) In-plant control for water minimization and wastewater reuse: A case study in pasta plants of Alexandria Flour Mills and Bakeries Company, Egypt. *JCP 18*(14): 1403-1412.
2	Ahmad, J. & H. El-Dessouky (2008) Design of a modified low cost treatment system for the recycling and reuse of laundry waste water. *RCR 52*(7): 973-978.
3	Al-Yaqout, A. F., P. A. Koushki & M. F. Hamoda (2002) Public opinion and siting solid waste landfills in Kuwait. *RCR 35*(4): 215-227.
4	Allwood, J. M., S. E. Laursen, S. N. Russell, C. M. de Rodríguez, & N. M. P. Bocken (2008) An approach to scenario analysis of the sustainability of an industrial sector applied to clothing and textiles in the UK. *JCP 16*(12): 1234-1246.
5	Alonso-Santurde, R., A. Coz, N. Quijorna, J. R. Viguri, & A. Andrés (2010) Valorization of Foundry Sand in Clay Bricks at Industrial Scale. *JIE 14*(2): 217-230.
6	Anand, V., H. N. Chanakya, & M. G. C. Rajan (1991) Solid phase fermentation of leaf biomass to biogas. *RCR 6*(1): 23-33.
7	Arbiza, M. J., A. Bonfill, G. Guillén, F. D. Mele, A. Espuña, & L. Puigjaner (2008) Metaheuristic multiobjective optimisation approach for the scheduling of multiproduct batch chemical plants. *JCP 16*(2): 233-244.
8	Aryee, B. N. A., B. K. Ntibery, & E. Atorkui (2003) Trends in the small-scale mining of precious minerals in Ghana: A perspective on its environmental impact. *JCP 11*(2): 131-140.
9	Ayres, R. U. (1995) Life cycle analysis: A critique. *RCR 14*(3-4): 199-223.
10	Ayres, R. U. & L. W. Ayres (1999) The life-cycle of chlorine, part IV: Accounting for persistent cyclic organo-chlorines. *JIE 3*(2-3): 121-159.
11	Badawi, M. A., M. M. El-Shinnawi, F. C. Blanc, D. L. Wise, & S. A. El-Shimi (1992) Production of acetic acid from thermally treated sewage sludge in an upflow anaerobic reactor. *RCR 7*(1-3): 201-212.
12	Baldwin, J. S., K. Ridgway, B. Winder, & R. Murray (2004) Modelling industrial ecosystems and the "problem" of evolution. *PIE 1*(1-3): 39-60.
13	Barnard, R. & G. Olivetti (1990) Limiting environmental impact by waste management. *RCR 4*(1-2): 51-62.
14	Baumgartner, R. J. & C. Zielowski (2007) Analyzing zero emission strategies regarding impact on organizational culture and contribution to sustainable development. *JCP 15*(13-14): 1321-1327.
15	Bengtsson, M. & A. M. Tillman (2004) Actors and interpretations in an environmental controversy: The Swedish debate on sewage sludge use in agriculture. *RCR 42*(1): 65-82.
16	Bergsdal, H., A. H. Strømman, & E. G. Hertwich (2005) Environmental assessment of two waste incineration strategies for Central Norway. *IJLCA 10*(4): 263-272.
17	Bitterman, M., V. L. Velasco, & F. Wright (2009) Using strategic sustainable development as an approach to conflict resolution. *PIE 6*(3): 314-334.
18	Björklund, A. & G. Finnveden (2005) Recycling revisited - Life cycle comparisons of global warming impact and total energy use of waste management strategies. *RCR 44*(4): 309-317.
19	Boons, F. & N. Roome (2000) Industrial ecology as a cultural phenomenon: On objectivity as a normative position. *JIE 4*(2): 49-54.
20	Borja, R., M. M. Duran, A. Martin, M. Luque, & V. Alonso (1994) Influence of immobilization supports on the kinetic constants of anaerobic digestion of cheese whey. *RCR 10*(4): 329-339.
21	Brent, A. C., M. B. Rohwer, E. Friedrich, & H. von Blottnitz (2002) Status of life cycle assessment and engineering research in South Africa. *IJLCA 7*(3): 167-172.
22	Brisson, I. (1993) Packaging waste and the environment: Economics and policy. *RCR 8*(3-4): 183-292.
23	Bunge, J., E. Cohen-Rosenthal, & A. Ruiz-Quintanilla (1996) Employee participation in pollution reduction: Preliminary analysis of the Toxics Release Inventory. *JCP 4*(1): 9-16.
24	Burgess, A. A. & D. J. Brennan (2001) Desulfurisation of gas oil: A case study in environmental and economic assessment. *JCP 9*(5): 465-472.
25	Canals, L. M. I., A. Chapagain, S. Orr, J. Chenoweth, A. Anton, & R. Clift (2010) Assessing freshwater use impacts in LCA, part 2: Case study of broccoli production in the UK and Spain. *IJLCA 15*(6): 598-607.
26	Castillo Berthier, H. (2003) Garbage, work and society. *RCR 39*(3): 193-210.
27	Cazcarro, I., R. D. Pac, & J. Sánchez-Chóliz (2010) Water consumption based on a disaggregated social accounting matrix of huesca (Spain). *JIE 14*(3): 496-511.
28	Ceulemans, K. & M. De Prins (2010) Teacher's manual and method for SD integration in curricula. *JCP 18*(7): 645-651.

29	Chaya, W. & S. H. Gheewala (2007) Life cycle assessment of MSW-to-energy schemes in Thailand. *JCP 15*(15): 1463-1468.
30	Chitra, S., K. Paramasivan, P. K. Sinha, & K. B. Lal (2004) Ultrasonic treatment of liquid waste containing EDTA. *JCP 12*(4): 429-435.
31	Chiu, S. Y., J. H. Huang, C. S. Lin, Y. H. Tang, W. H. Chen, & S. C. Su (1999) Applications of a corporate synergy system to promote cleaner production in small and medium enterprises. *JCP 7*(5): 351-358.
32	Christiansen, K. & D. Kardel (2005) Environmental certificates - Danish lessons. *JCP 13*(8): 863-866.
33	Ciroth, A., M. Hagelüken, G. W. Sonnemann, F. Castells, & G. Fleischer (2002) Geographical and technological differences in life cycle inventories: Shown by the use of process models for waste incinerators: Part I. Technological and geographical differences. *IJLCA 7*(5): 295-300.
34	Conn, W. D. (1993) Initiating the development of an integrated waste management curriculum. *RCR 8*(1-2): 55-61.
35	Costa, S. & M. Scoble (2006) An interdisciplinary approach to integrating sustainability into mining engineering education and research. *JCP 14*(3-4): 366-373.
36	Costa, I. & P. Ferrão (2010) A case study of industrial symbiosis development using a middle-out approach. *JCP 18*(10-11): 984-992.
37	Crofton, F. S. (2000) Educating for sustainability: Opportunities in undergraduate engineering. *JCP 8*(5): 397-405.
38	D'Alessandro, S., T. Luzzati, & M. Morroni (2010) Energy transition towards economic and environmental sustainability: feasible paths and policy implications (DOI:10.1016/j.jclepro.2009.10.015). *JCP 18*(6): 532-539.
39	Davis, G. & S. Herat (2008) Electronic waste: The local government perspective in Queensland, Australia. *RCR 52*(8-9): 1031-1039.
40	de Arruda Guelli Ulson de Souza, S. M., A. R. Melo, & A. A. U. de Souza (2006) Re-utilisation conditions of wastewaters from textiles industries. *RCR 49*(1): 1-13.
41	De Benedetto, L. & J. Klemeš (2009) The Environmental Performance Strategy Map: an integrated LCA approach to support the strategic decision-making process. *JCP 17*(10): 900-906.
42	Demirbaş, A. (1999) Recycling of lithium from borogypsum by leaching with water and leaching kinetics. *RCR 25*(2): 125-131.
43	Dimitroff-Regatschnig, H. & H. Schnitzer (1998) A techno-economic approach to link waste minimization technologies with the reduction of corporate environmental costs: Effects on the resource and energy efficiency of production. *JCP 6*(3-4): 213-225.
44	Dodbiba, G., T. Nukaya, Y. Kamioka, Y. Tanimura, & T. Fujita (2009) Removal of arsenic from wastewater using iron compound: Comparing two different types of adsorbents in the context of LCA. *RCR 53*(12): 688-697.
45	Donnelly, K., Z. Beckett-Furnell, S. Traeger, T. Okrasinski, & S. Holman (2006) Eco-design implemented through a product-based environmental management system. *JCP 14*(15-16): 1357-1367.
46	Dubreuil, A., S. B. Young, J. Atherton, & T. P. Gloria (2010) Metals recycling maps and allocation procedures in life cycle assessment. *IJLCA 15*(6): 621-634.
47	Ekvall, T. & B. P. Weidema (2004) System boundaries and input data in consequential life cycle inventory analysis. *IJLCA 9*(3): 161-171.
48	Ekvall, T. & G. Finnveden (2001) Allocation in ISO 14041 - a critical review. *JCP 9*(3): 197-208.
49	Emery, S. B., D. N. Smith, M. R. Gaterell, G. Sammons, & D. Moon (2007) Estimation of the recycled content of an existing construction project. *RCR 52*(2): 395-409.
50	Erixon, A. M., R. Carlson, K. Flemström, & A. C. Pålsson (2004) The data quality foundation in OMNIITOX information system. *IJLCA 9*(5): 333.
51	Farrant, L., S. I. Olsen, & A. Wangel (2010) Environmental benefits from reusing clothes. *IJLCA 15*(7): 726-736.
52	Fehr, M., M. S. M. V. de Castro, & M. D. R. Calçado (2000) A practical solution to the problem of household waste management in Brazil. *RCR 30*(3): 245-257.
53	Finkbeiner, M., A. Inaba, R. B. H. Tan, K. Christiansen, & H. J. Klüppel (2006) The new international standards for life cycle assessment: ISO 14040 and ISO 14044. *IJLCA 11*(2): 80-85.
54	Finnveden, G. (1996) Solid waste treatment within the framework of life cycle assessment: Metals in municipal solid waste landfills. *IJLCA 1*(2): 74-78.
55	Forslind, K. H. (2005) Implementing extended producer responsibility: The case of Sweden's car scrapping scheme. *JCP 13*(6): 619-629.
56	Fratila, D. (2009) Evaluation of near-dry machining effects on gear milling process efficiency. *JCP 17*(9): 839-845.
57	Frischknecht, R., N. Jungbluth, H. J. Althaus, G. Doka, R. Dones, T. Heck, et al (2005) The ecoinvent database: Overview and methodological framework. *IJLCA 10*(1): 3-9.
58	Gaballah, I., M. Djona, J. C. Mugica, & R. Solozobal (1994) Valuable metals recovery from spent catalysts by selective chlorination. *RCR 10*(1-2): 87-96.
59	Gao, C., H. Hou, J. Zhang, H. Zhang, & W. Gong (2006) Education for regional sustainable development: experiences from the education framework of HHCEPZ project. *JCP 14*(9-11): 994-1002.
60	Geerlings, H., R. Klementschitz, & C. Mulley (2006) Development of a methodology for benchmarking public transportation organisations: A practical tool based on an industry sound methodology. *JCP 14*(2): 113-123.
61	Gernuks, M., J. Buchgeister, & L. Schebek (2007) Assessment of environmental aspects and determination of environmental targets within environmental management systems (EMS) - development of a procedure for Volkswagen. *JCP 15*(11-12): 1063-1075.
62	Godfrey, S., P. Labhasetwar, & S. Wate (2009) Greywater reuse in residential schools in Madhya Pradesh, India-A case study of cost-benefit analysis. *RCR 53*(5): 287-293.
63	Gold, S. & F. Rubik (2009) Consumer attitudes towards timber as a construction material and towards timber frame houses - selected findings of a representative survey among the German population. *JCP 17*(2): 303-309.
64	Graedel, T. E., M. Bertram, & B. Reck (2005) Exploratory data analysis of the multilevel anthropogenic zinc cycle. *JIE 9*(3): 91-108.

65	Grigg, S. V. L. & A. D. Read (2001) A discussion on the various methods of application for landfill tax credit funding for environmental and community projects. *RCR 32*(3-4): 389-409.
66	Gutterres, M., P. M. Aquim, J. B. Passos, & J. O. Trierweiler (2010) Water reuse in tannery beamhouse process. *JCP 18*(15): 1543-1550.
67	Haibin, L. & L. Zhenling (2010) Recycling utilization patterns of coal mining waste in China. *RCR 54*(12): 1331-1340.
68	Han, G. S. A., N. Bektaş, & M. S. Öncel (2010) Separate collection practice of packaging waste as an example of Küçükçekmece, Istanbul, Turkey. *RCR 54*(12): 1317-1321.
69	Hansen, J. A. & M. Lehmann (2006) Agents of change: universities as development hubs. *JCP 14*(9-11): 820-829.
70	Hayashi, K., N. Itsubo, & A. Inaba (2000) Development of damage function for stratospheric ozone layer depletion: A tool towards the improvement of the quality of life cycle impact assessment. *IJLCA 5*(5): 265-272.
71	Heiskanen, E., B. Brohmann, U. R. Fritsche, & N. Schönherr (2009) Policies to promote sustainable consumption: Framework for a future-oriented evaluation. *PIE 6*(4): 387-403.
72	Helland, A., H. Kastenholz, & M. Siegrist (2008) Precaution in practice: Perceptions, procedures, and performance in the Nanotech Industry. *JIE 12*(3): 449-458.
73	Hellweg, S. & G. Geisler (2003) Life cycle impact assessment of pesticides: When active substances are spread into the environment. Zurich, 27 March 2003. *IJLCA 8*(5): 310-312.
74	Hischier, R., H. J. Althaus, & F. Werner (2005) Developments in wood and packaging materials life cycle inventories in ecoinvent. *IJLCA 10*(1): 50-58.
75	Honkasalo, A. (2007) Work and eco-efficiency: Opportunities and limitations. *PIE 4*(6): 484-494.
76	Horiuchi, J. I., K. Tada, M. Kobayashi, T. Kanno, & K. Ebie (2004) Biological approach for effective utilization of worthless onions - Vinegar production and composting. *RCR 40*(2): 97-109.
77	Hospido, A., M. T. Moreira, M. Fernández-Couto, & G. Feijoo (2004) Environmental performance of a municipal wastewater treatment plant. *IJLCA 9*(4): 261-271.
78	Hubal, E. A. C. & M. R. Overcash (1995) Net-waste-reduction analysis applied to zero-water discharge systems for chromic acid electroplating. *JCP 3*(3): 161-167.
79	Hurlimann, A. C. (2009) Water supply in regional Victoria Australia: A review of the water cartage industry and willingness to pay for recycled water. *RCR 53*(5): 262-268.
80	Inada, K., R. Matsuda, C. Fujiwara, M. Nomura, T. Tamon, I. Nishihara, et al (2001) Identification of plastics by infrared absorption using InGaAsP laser diode. *RCR 33*(2): 131-146.
81	Insa, E., M. Zamorano, & R. López (2010) Critical review of medical waste legislation in Spain. *RCR 54*(12): 1048-1059.
82	Jayaraman, K. & D. Bhattacharyya (2004) Mechanical performance of woodfibre-waste plastic composite materials. *RCR 41*(4): 307-319.
83	Johannsen, K. S. (2002) Combining voluntary agreements and taxes - An evaluation of the Danish agreement scheme on energy efficiency in industry. *JCP 10*(2): 129-141.
84	Jolliet, O. & P. Crettaz (1997) Fate coefficients for the toxicity assessment of air pollutants. *IJLCA 2*(2): 104-110.
85	Jolly, R. & C. Rhin (1994) The recycling of lead-acid batteries: Production of lead and polypropylene. *RCR 10*(1-2): 137-143.
86	Jørgensen, A. M., P. E. Ywema, N. Frees, S. Exner, & R. Bracke (1996) Transportation in LCA: A comparative evaluation of the importance of transport in four LCAs. *IJLCA 1*(4): 218-220.
87	Kaijuka, E. (2007) GIS and rural electricity planning in Uganda. *JCP 15*(2): 203-217.
88	Karavanas, A., A. Chaloulakou, & N. Spyrellis (2009) Evaluation of the implementation of best available techniques in IPPC context: an environmental performance indicators approach. *JCP 17*(4): 480-486.
89	Karthick, R., G. Kumaraprasad, & B. Sruti (2010) Hybrid optimization approach for water allocation and mass exchange network. *RCR 54*(11): 783-792.
90	Kernel, P. (2005) Creating and implementing a model for sustainable development in tourism enterprises. *JCP 13*(2): 151-164.
91	Kim, S. & B. E. Dale (2005) Life cycle assessment study of biopolymers (Polyhydroxyalkanoates) derived from no-tilled corn. *IJLCA 10*(3): 200-210.
92	Kim, S. & B. E. Dale (2009) Regional variations in greenhouse gas emissions of biobased products in the United States-corn-based ethanol and soybean oil. *IJLCA 14*(6): 540-546.
93	Kleijn, R., A. Tukker, & E. van der Voet (1997) Chlorine in the Netherlands, part I, an overview. *JIE 1*(1): 95-116.
94	Kløverpris, J., H. Wenzel, M. Banse, L. Milà i Canals, & A. Reenberg (2008) Conference and workshop on modelling global land use implications in the environmental assessment of biofuels. *IJLCA 13*(3): 178-183.
95	Korhonen, J. (2005) Theory of industrial ecology: the case of the concept of diversity. *PIE 2*(1): 35-72.
96	Korhonen, J. & P. A. Strachan (2004) Editorial: Towards progress in industrial ecology. *PIE 1*(1-3): 1-23.
97	Kremer, M., G. Goldhan, & M. Heyde (1998) Waste treatment in product specific life cycle inventories: An approach of material-related modelling: Part I: Incineration. *IJLCA 3*(1): 47-55.
98	Kronenberg, J. (2006) Industrial ecology and ecological economics. *PIE 3*(1-2): 95-113.
99	Kurczewski, P. & A. Lewandowska (2010) ISO 14062 in theory and practice-ecodesign procedure. Part 2: Practical application. *IJLCA 15*(8): 777-784.
100	La Motta, S., D. Santino, P. Ancona, & M. Weiss (2005) CO2 emission accounting for the non-energy use of fossil fuels in Italy: A comparison between NEAT model and the IPCC approaches. *RCR 45*(3): 310-330.
101	Laner, D. & H. Rechberger (2007) Treatment of cooling appliances: Interrelations between environmental protection, resource conservation, and recovery rates. *RCR 52*(1): 136-155.
102	Lave, L., N. Conway-Schempf, J. Harvey, D. Hart, T. Bee, & C. MacCracken (1998) Recycling Postconsumer Nylon Carpet: A Case Study of the Economics and Engineering Issues Associated with Recycling Postconsumer Goods. *JIE 2*(1): 117-126.
103	Lee, H. B., N. W. Cho, & Y. S. Hong (2010) A hierarchical end-of-life decision model for determining the economic levels of remanufacturing and disassembly under environmental regulations. *JCP 18*(13): 1276-1283.

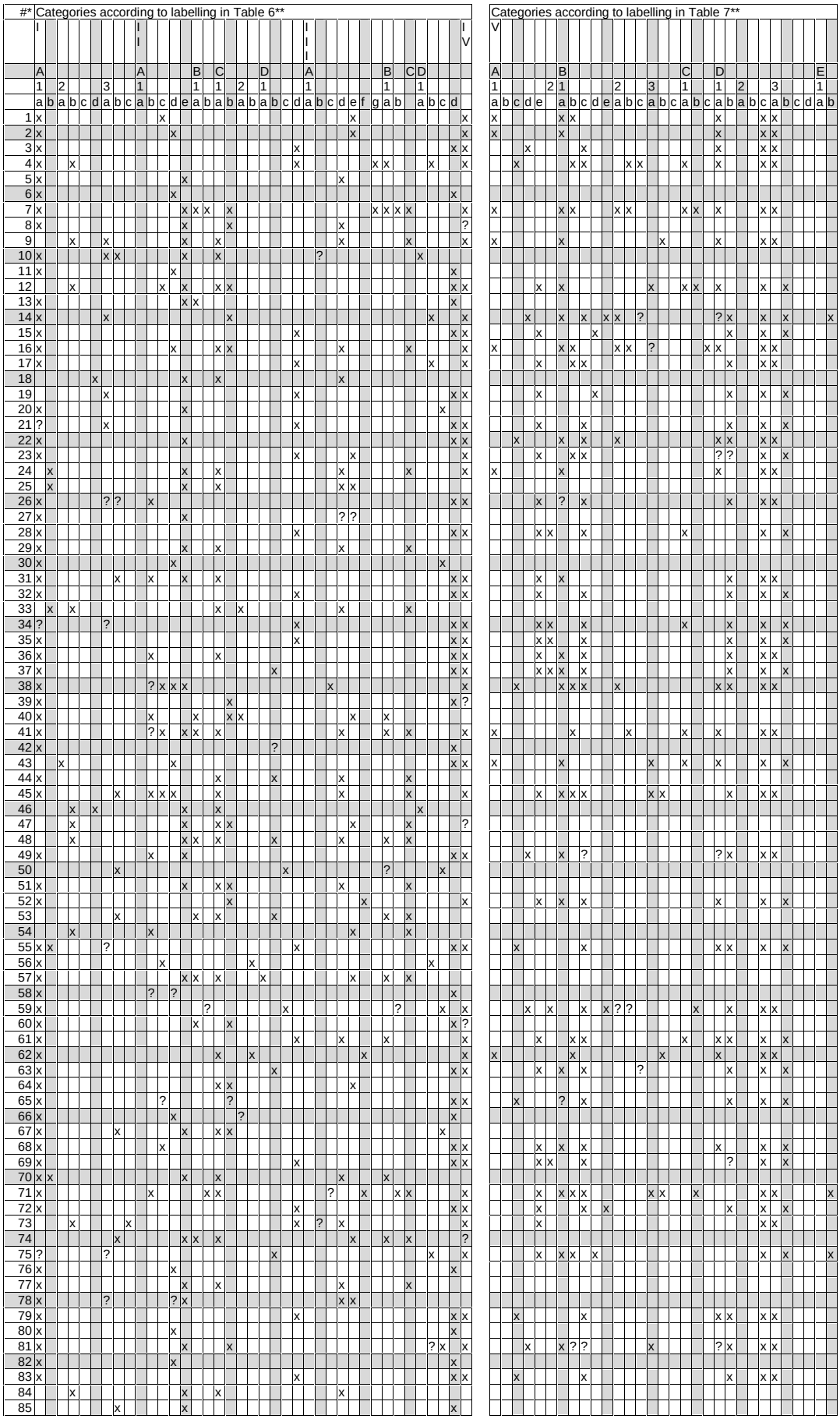
104	Leibrecht, S. (2005) Fundamental principles for CAD-based ecological assessments. *IJLCA 10*(6): 436-444.
105	Levine, S. H. (1999) Products and ecological models: A population ecology perspective. *JIE 3*(2-3): 47-62.
106	Lima, J. S., J. E. G. De Queiroz, & H. B. Freitas (2004) Effect of selected and non-selected urban waste compost on the initial growth of corn. *RCR 42*(4): 309-315.
107	Lin, H. Y., G. H. Chen, P. H. Lee, & C. H. Lin (2010) An interactive optimization system for the location of supplementary recycling depots. *RCR 54*(10): 615-622.
108	Liu, X. & V. Anbumozhi (2009) Determinant factors of corporate environmental information disclosure: an empirical study of Chinese listed companies. *JCP 17*(6): 593-600.
109	Lobendahn Wood, M. D. K., F. Mathieux, D. Brissaud, & D. Evrard (2010) Results of the first adapted design for sustainability project in a South Pacific small island developing state: Fiji. *JCP 18*(18): 1775-1785.
110	Lusugga Kironde, J. M. & M. Yhdego (1997) The governance of waste management in urban Tanzania: Towards a community based approach. *RCR 21*(4): 213-226.
111	Mäenpää, I. & A. Juutinen (2001) Materials flows in Finland: Resource use in a small open economy. *JIE 5*(3): 33-46.
112	Mah, D. Y. S., C. H. J. Bong, F. J. Putuhena, & S. Said (2009) A conceptual modeling of ecological greywater recycling system in Kuching city, Sarawak, Malaysia. *RCR 53*(3): 113-121.
113	Malmodin, J., A. S. Moberg, D. Lundén, G. Finnveden, & N. Lövehagen (2010) Greenhouse gas emissions and operational electricity use in the ICT and entertainment & Media sectors. *JIE 14*(5): 770-790.
114	Marvuglia, A., M. Cellura, & R. Heijungs (2010) Toward a solution of allocation in life cycle inventories: The use of least-squares techniques. *IJLCA 15*(9): 1020-1040.
115	Matsuno, Y. & M. Betz (2000) Development of life cycle inventories for electricity grid mixes in Japan. *IJLCA 5*(5): 295-305.
116	Maurice, B., R. Frischknecht, V. Coelho-Schwirtz, & K. Hungerbühler (2000) Uncertainty analysis in life cycle inventory. Application to the production of electricity with French coal power plants. *JCP 8*(2): 95-108.
117	Maxwell, D., W. Sheate, & R. van der Vorst (2006) Functional and systems aspects of the sustainable product and service development approach for industry. *JCP 14*(17): 1466-1479.
118	Meech, J. A., M. McPhie, K. Clausen, Y. Simpson, B. Lang, E. Campbell, et al (2006) Transformation of a derelict mine site into a sustainable community: The Britannia project. *JCP 14*(3-4): 349-365.
119	Milà, L., X. Domènech, J. Rieradevall, P. Fullana, & R. Puig (1998) Application of life cycle assessment to footwear. *IJLCA 3*(4): 203-208.
120	Milà i Canals, L., C. Bauer, J. Depestele, A. Dubreuil, R. F. Knuchel, G. Gaillard, et al (2007) Key elements in a framework for land use impact assessment within LCA. *IJLCA 12*(1): 5-15.
121	Milanez, B. & T. Bührs (2009) Extended producer responsibility in Brazil: the case of tyre waste. *JCP 17*(6): 608-615.
122	Molander, S., P. Lidholm, D. Schowanek, M. Recasens, P. Fullana i Palmer, F. M. Christensen, et al (2004) OMNIITOX - Operational life-cycle impact assessment models and information tools for practitioners. *IJLCA 9*(5): 282-288.
123	Morris, J. & J. Bagby (2008) Measuring environmental value for natural lawn and garden care practices. *IJLCA 13*(3): 226-234.
124	Mousazadeh, H., A. Keyhani, H. Mobli, U. Bardi, G. Lombardi, & T. el Asmar (2009) Technical and economical assessment of a multipurpose electric vehicle for farmers. *JCP 17*(17): 1556-1562.
125	Muñoz, I., J. Rieradevall, X. Domènech, & C. Gazulla (2006) Using LCA to assess eco-design in the automotive sector: Case study of a polyolefinic door panel. *IJLCA 11*(5): 323-334.
126	Muttamara, S. (1996) Wastewater characteristics. *RCR 16*(1-4): 145-159.
127	Nehete, P. N., N. K. Shah, & R. M. Kothari (1991) Recycling of mother liquor of sorbose and glucose for hexitol production. *RCR 5*(1): 81-87.
128	Niederl-Schmidinger, A. & M. Narodoslawsky (2008) Life Cycle Assessment as an engineer's tool? *JCP 16*(2): 245-252.
129	Nishioka, Y., J. I. Levy, G. A. Norris, D. H. Bennett, & J. D. Spengler (2005) A risk-based approach to health impact assessment for input-output analysis: Part 2: Case study of insulation. *IJLCA 10*(4): 255-262.
130	O'Rourke, D. (2005) Market movements: Nongovernmental organization strategies to influence global production and consumption. *JIE 9*(1-2): 115-128.
131	Odum, E. P. (1997) Commentary: source reduction, input management and dual capitalism. *JCP 5*(1-2): 123.
132	Olsson, S., E. Kärrman, & J. P. Gustafsson (2006) Environmental systems analysis of the use of bottom ash from incineration of municipal waste for road construction. *RCR 48*(1): 26-40.
133	Owens, J. W. (1997) Life-cycle assessment: Constraints on moving from inventory to impact assessment. *JIE 1*(1): 37-49.
134	Pappa, G., C. Boukouvalas, C. Giannaris, N. Ntaras, V. Zografos, K. Magoulas, et al (2001) The selective dissolution/precipitation technique for polymer recycling: A pilot unit application. *RCR 34*(1): 33-44.
135	Paulsen, J. H. (2003) The Maintenance of Linoleum and PVC Floor Coverings in Sweden: The Significance of the Usage Phase in an LCA. *IJLCA 8*(6): 357-364.
136	Pedersen Weidema, B. (1993) Market aspects in product life cycle inventory methodology. *JCP 1*(3-4): 161-166.
137	Pesonen, H. L., T. Ekvall, G. Fleischer, G. Huppes, C. Jahn, Z. S. Klos, et al (2000) Framework for scenario development in LCA. *IJLCA 5*(1): 21-30.
138	Pfeifer, R. P. (1996) Comparison between Filament Lamps and Compact Fluorescent Lamps. *IJLCA 1*(1): 8-14.
139	Ponton, J. W. (2009) Biofuels: Thermodynamic sense and nonsense. *JCP 17*(10): 896-899.
140	Poon, C. S. & D. Chan (2007) The use of recycled aggregate in concrete in Hong Kong. *RCR 50*(3): 293-305.
141	Pye, M. & A. McKane (2000) Making a stronger case for industrial energy efficiency by quantifying non-energy benefits. *RCR 28*(3-4): 171-183.
142	Qiao, G., J. Gao, & Z. Jin (2002) Resources consumption and wastes emission analysis for two manufacture processes of siliconit. *RCR 36*(4): 355-363.
143	Randall, P. M. (1993) Investigation of cleaner technologies to minimize automotive coolant wastes. *JCP 1*(2): 67-75.
144	Ras, P. J., W. J. V. Vermeulen, & S. L. Saalmink (2007) Greening global product chains: Bridging barriers in the north-

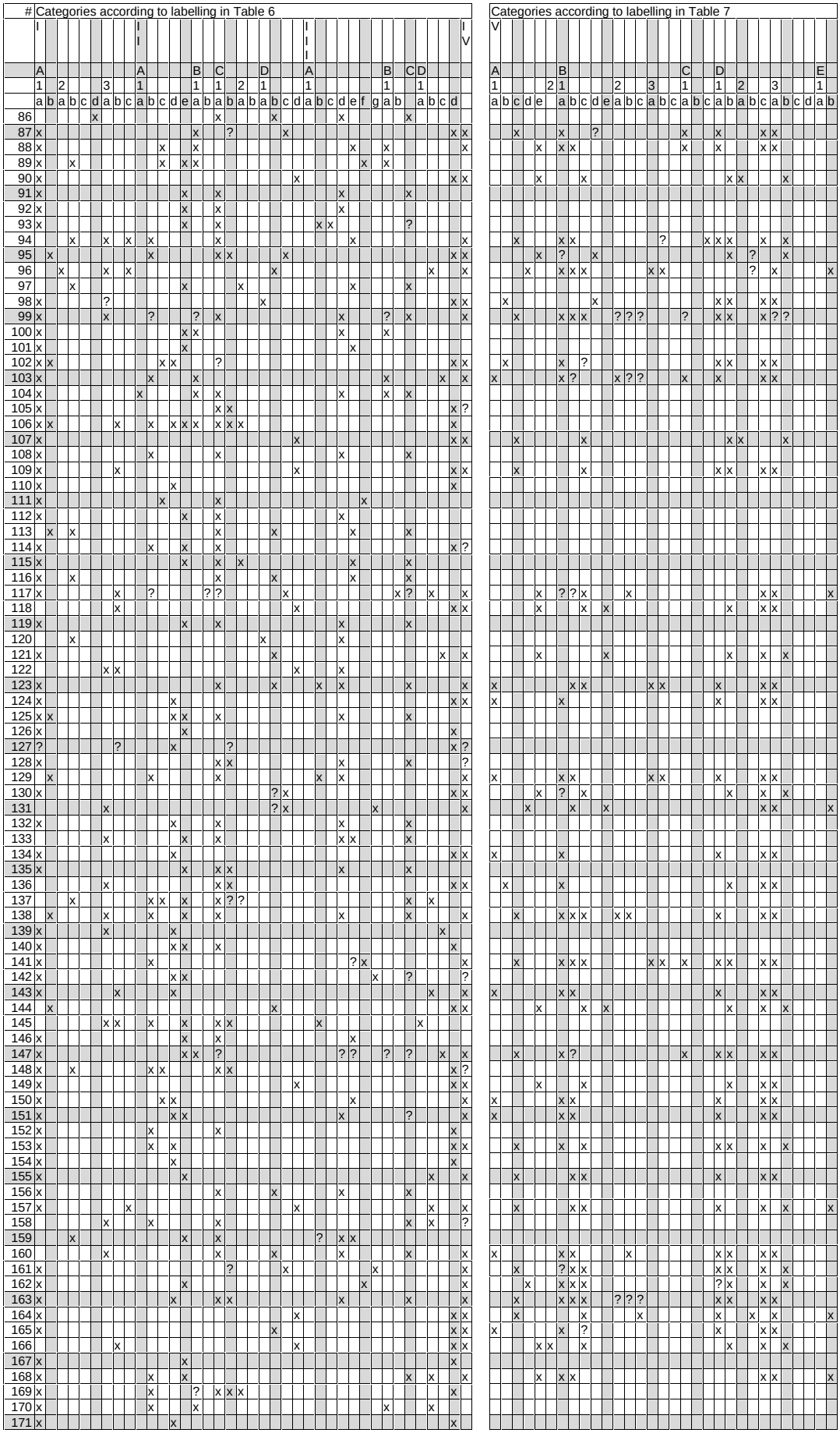
	south cooperation. An exploratory study of possibilities for improvement in the product chains of table grape and wine connecting South Africa and the Netherlands. *PIE 4*(6): 401-417.
145	Reijnders, L. (2006) Cleaner nanotechnology and hazard reduction of manufactured nanoparticles. *JCP 14*(2): 124-133.
146	Ren, T. & M. K. Patel (2009) Basic petrochemicals from natural gas, coal and biomass: Energy use and CO2 emissions. *RCR 53*(9): 513-528.
147	Rice, G., R. Clift, & R. Burns (1997) LCA software review: Comparison of currently available European LCA software. *IJLCA 2*(1): 53-59.
148	Ristola, P. & M. Mirata (2007) Industrial symbiosis for more sustainable, localised industrial systems. *PIE 4*(3-4): 184-204.
149	Rodríguez, G., F. J. Alegre, & G. Martínez (2007) The contribution of environmental management systems to the management of construction and demolition waste: The case of the Autonomous Community of Madrid (Spain). *RCR 50*(3): 334-349.
150	Roy, C., B. Labrecque, & B. de Caumia (1990) Recycling of scrap tires to oil and carbon black by vacuum pyrolysis. *RCR 4*(3): 203-213.
151	Ruggieri, L., E. Cadena, J. Marínez-Blanco, C. M. Gasol, J. Rieradevall, X. Gabarrell, et al (2009) Recovery of organic wastes in the Spanish wine industry. Technical, economic and environmental analyses of the composting process. *JCP 17*(9): 830-838.
152	Saar, S., M. Stutz, & V. M. Thomas (2004) Towards intelligent recycling: A proposal to link bar codes to recycling information. *RCR 41*(1): 15-22.
153	Saint-Ges, V. & M. C. Bélis-Bergouignan (2009) Ways of reducing pesticides use in Bordeaux vineyards. *JCP 17*(18): 1644-1653.
154	Sarti, A., M. L. Garcia, M. Zaiat, & E. Foresti (2007) Domestic sewage treatment in a pilot-scale anaerobic sequencing batch biofilm reactor (ASBBR). *RCR 51*(1): 237-247.
155	Schandl, H., F. Poldy, G. M. Turner, T. G. Measham, D. H. Walker, & N. Eisenmenger (2008) Australia's resource use trajectories. *JIE 12*(5-6): 669-685.
156	Schmidt, A. C., A. A. Jensen, A. U. Clausen, O. Kamstrup, & D. Postlethwaite (2004) A comparative life cycle assessment of building insulation products made of stone wool, paper wool and flax: Part 1: Background, goal and scope, life cycle inventory, impact assessment and interpretation. *IJLCA 9*(1): 53-66.
157	Schneider, F., G. Kallis, & J. Martinez-Alier (2010) Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. *JCP 18*(6): 511-518.
158	Seiffert, M. E. B. & C. Loch (2005) Systemic thinking in environmental management: Support for sustainable development. *JCP 13*(12): 1197-1202.
159	Shah, V. P. & R. J. Ries (2009) A characterization model with spatial and temporal resolution for life cycle impact assessment of photochemical precursors in the united States. *IJLCA 14*(4): 313-327.
160	Shapiro, K. G. (2001) Incorporating costs in LCA. *IJLCA 6*(2): 121-123.
161	Sharma, V. K., P. van Beukering, & B. Nag (1997) Environmental and economic policy analysis of waste paper trade and recycling in India. *RCR 21*(1): 55-70.
162	Sibley, S. F. & W. C. Butterman (1995) Metals recycling in the United States. *RCR 15*(3-4): 259-267.
163	Skordilis, A. (2004) Modelling of integrated solid waste management systems in an island. *RCR 41*(3): 243-254.
164	Skouloudis, A., K. Evangelinos, & F. Kourmousis (2010) Assessing non-financial reports according to the Global Reporting Initiative guidelines: evidence from Greece. *JCP 18*(5): 426-438.
165	Sookkumnerd, C., N. Ito, & K. Kito (2007) Feasibility of husk-fuelled steam engines as prime mover of grid-connected generators under the Thai very small renewable energy power producer (VSPP) program. *JCP 15*(3): 266-274.
166	Steiner, G. & A. Posch (2006) Higher education for sustainability by means of transdisciplinary case studies: an innovative approach for solving complex, real-world problems. *JCP 14*(9-11): 877-890.
167	Stessel, R. I. (1991) A new trommel model. *RCR 6*(1): 1-22.
168	Stoll, U. (1996) Liquid effluent treatment, sewage sludge management and industrial effluent standards. *RCR 16*(1-4): 113-133.
169	Su, J., G. H. Huang, B. D. Xi, X. S. Qin, S. L. Huo, Y. H. Jiang, et al (2010) Long-term panning of waste diversion under interval and probabilistic uncertainties. *RCR 54*(7): 449-461.
170	Swanson, M., A. Weissman, G. Davis, M. L. Socolof, & K. Davis (2005) Developing priorities for greener state government purchasing: A California case study. *JCP 13*(7): 669-677.
171	Takada, T., I. Hashimoto, K. Tsutsumi, Y. Shibata, S. Yamamuro, T. Kamada, et al (1995) Utilization of coal ash from fluidized-bed combustion boilers as road base material. *RCR 14*(2): 69-77.
172	Tan, R. R., L. M. A. Briones, & A. B. Culaba (2007) Fuzzy data reconciliation in reacting and non-reacting process data for life cycle inventory analysis. *JCP 15*(10): 944-949.
173	Tan, R. R., D. K. Sum Ng, & D. C. Yee Foo (2009) Pinch analysis approach to carbon-constrained planningfor sustainable power generation. *JCP 17*(10): 940-944.
174	Tharumarajah, A. & P. Koltun (2010) Improving environmental performance of magnesium instrument panels. *RCR 54*(12): 1189-1195.
175	Tian, Y. & F. Yang (2007) Reduction of hexavalent chromium by polypyrrole-modified steel mesh electrode. *JCP 15*(15): 1415-1418.
176	Toffoletto, L., L. Deschênes, & R. Samson (2005) LCA of ex-situ bioremediation of diesel-contaminated soil. *IJLCA 10*(6): 406-416.
177	Tramšek, M., A. Goršek, & P. Glavič (2007) Methodology for determination of anaerobic digestion kinetics using a bench top digester. *RCR 51*(1): 225-236.
178	Tudor, T. L., S. W. Barr, & A. W. Gilg (2007) Linking intended behaviour and actions: A case study of healthcare waste management in the Cornwall NHS. *RCR 51*(1): 1-23.
179	Ulgiati, S., S. Bargigli, & M. Raugei (2007) An emergy evaluation of complexity, information and technology, towards maximum power and zero emissions. *JCP 15*(13-14): 1359-1372.

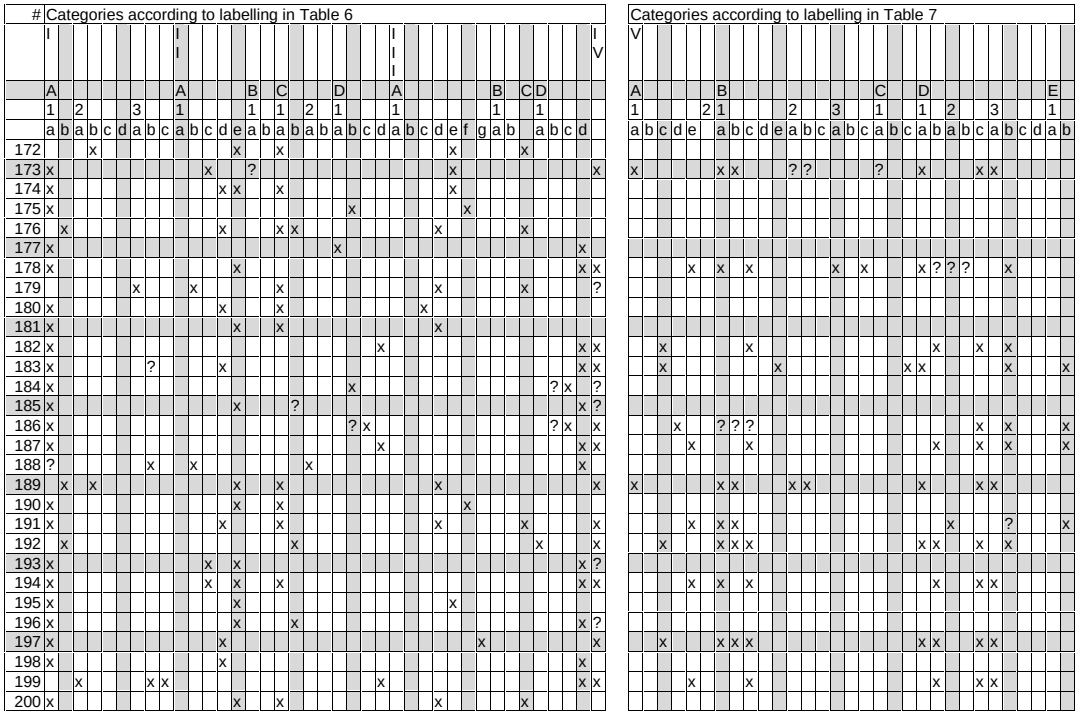
180	Upham, P., P. Thornley, J. Tomei, & P. Boucher (2009) Substitutable biodiesel feedstocks for the UK: a review of sustainability issues with reference to the UK RTFO. *JCP 17*(SUPPL. 1): S37-S45.
181	Van Caneghem, J., I. Vermeulen, C. Block, P. Cramm, R. Mortier, & C. Vandecasteele (2010) Abiotic depletion due to resource consumption in a steelwork assessed by five different methods. *RCR 54*(12): 1067-1073.
182	Varnäs, A., B. Balfors, & C. Faith-Ell (2009) Environmental consideration in procurement of construction contracts: current practice, problems and opportunities in green procurement in the Swedish construction industry. *JCP 17*(13): 1214-1222.
183	Veiga, M. M., D. Nunes, B. Klein, J. A. Shandro, P. C. Velasquez, & R. N. Sousa (2009) Mill leaching: a viable substitute for mercury amalgamation in the artisanal gold mining sector? *JCP 17*(15): 1373-1381.
184	Vinodh, S. (2010) Improvement of agility and sustainability: A case study in an Indian rotary switches manufacturing organisation. *JCP 18*(10-11): 1015-1020.
185	Visvanathan, C. (1996) Hazardous waste disposal. *RCR 16*(1-4): 201-212.
186	Wagner, T. & P. Arnold (2008) A new model for solid waste management: an analysis of the Nova Scotia MSW strategy. *JCP 16*(4): 410-421.
187	Waldron, D. & P. Leung (2009) Strategic leadership towards sustainability: a master's programme on sustainability. *PIE 6*(3): 307-313.
188	Wan Alwi, S. R., A. Aripin, & Z. A. Manan (2009) A generic graphical approach for simultaneous targeting and design of a gas network. *RCR 53*(10): 588-591.
189	Weinzettel, J. & J. Kovanda (2009) Assessing socioeconomic metabolism through hybrid life cycle assessment: The case of the Czech Republic. *JIE 13*(4): 607-621.
190	Weiss, M., M. L. Neelis, K. Blok, & M. K. Patel (2008) Non-energy use and related carbon dioxide emissions in Germany: A carbon flow analysis with the NEAT model for the period of 1990-2003. *RCR 52*(11): 1252-1265.
191	Williams, H., F. Wikström, & M. Löfgren (2008) A life cycle perspective on environmental effects of customer focused packaging development. *JCP 16*(7): 853-859.
192	Wilson, C. D. H. & I. D. Williams (2007) Kerbside collection: A case study from the north-west of England. *RCR 52*(2): 381-394.
193	Wung, T. C., S. H. Lin, & S. M. Huang (2006) Rainwater reuse supply and demand response in urban elementary school of different districts in Taipei. *RCR 46*(2): 149-167.
194	Yarime, M. (2009) Public coordination for escaping from technological lock-in: its possibilities and limits in replacing diesel vehicles with compressed natural gas vehicles in Tokyo. *JCP 17*(14): 1281-1288.
195	Yellishetty, M., P. G. Ranjith, & D. L. Kumar (2009) Metal concentrations and metal mobility in unsaturated mine wastes in mining areas of Goa, India. *RCR 53*(7): 379-385.
196	You, S. H., D. H. Tseng, G. L. Guo, & J. J. Yang (1999) The potential for the recovery and reuse of cooling water in Taiwan. *RCR 26*(1): 53-70.
197	Zah, R., R. Hischier, A. L. Leão, & I. Braun (2007) Curauá fibers in the automobile industry - a sustainability assessment. *JCP 15*(11-12): 1032-1040.
198	Zhelev, T. K. & K. A. Semkov (2004) Cleaner flue gas and energy recovery through pinch analysis. *JCP 12*(2): 165-170.
199	Zilahy, G., D. Huisingh, M. Melanen, V. D. Phillips, & J. Sheffy (2009) Roles of academia in regional sustainability initiatives: outreach for a more sustainable future. *JCP 17*(12): 1053-1056.
200	Zuoren, N., D. Xianghua, L. Guiqi, & Z. Tieyong (2001) Material Life Cycle Assessment in China. *IJLCA 6*(1): 47-48.

* IJLCA = International Journal of Life Cycle Assessment
JCP = Journal of Cleaner Production
JIE = Journal of Industrial Ecology
PIE = Progress in Industrial Ecology
RCR = Resources, Conservation & Recycling

Table A.2: Details of the categorisation of the 200 randomly sampled articles




Categories according to labelling in Table 6
Categories according to labelling in Table 7



* See Table A.1

** x = The category was considered to apply to the article

? = It was considered not to be clear whether the category applied to the article or not

blank = The category was considered not to apply to the article