

Two Decades of Publishing on Life Cycle Assessment in Spain. Main Issues, Key Agents, and a Comparison with Other Countries

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Received: 23 April 2013

Accepted: 2 April 2014

Abstract

The methodology of life cycle analysis (LCA) received strong institutional support in 2001 when the European Union (EU) published its green paper on integrated product policy (IPP). In fact, the European Commission itself highlighted the LCA as a cornerstone for the development of that policy. However, little remains known about the effective implementation of this tool in Spain. In order to start filling this gap, a review of scientific papers published in four of the main international journals on the matter has been carried out.

Among the 2,030 papers identified, 142 have at least one Spanish author. The topics most frequently addressed by these papers are agriculture and food, waste management, water, and the LCA methodology itself. Among other findings the study reveals a delay in Spain in this field compared to other countries, a certain similarity in the issues discussed and, finally, that the interest shown by the academic world is higher than that shown by the private sector.

Keywords: life cycle assessment (LCA), integrated product policy (IPP), sustainability, publications, Spain

Introduction

Within the present climate of mounting awareness regarding the duality of energy-saving climate change, there is an undeniable interest in all matters environmental among consumers, manufacturers, and legislators. On the one hand, firms need tools to help them improve the environmental performance of their products and processes, and on the other, public agencies require reliable and objective criteria in order to introduce public policies that drive sustainability. Accordingly, there are several authors who have

identified LCA as a support tool for the decision-making process of governments, businesses, consumer organizations, and environmental groups [1-3]. The spheres of decision in which LCA may be of help range from the general management of firms and institutions and the analysis of alternatives for public policies, to the design-stage selection of different specific characteristics for products and processes [4].

In this context it would be interesting to know the real situation of LCA both in business and in public policy. However, before directly analyzing these aspects it is worth pausing to learn something about the interest that this issue has garnered in more academic fields. The main objective

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Table 1. Publications chosen for the study and distribution of papers, 1993-2010.

Journal Name	Impact Factor 2013	Year of First Issue	Total No. of papers	Papers with Spanish authors
<i>International Journal of Life Cycle Assessment, IJLCA</i>	3.148	1996	1,044	84
<i>Journal of Cleaner Production, JCP</i>	2.425	1993	457	37
<i>Journal of Industrial Ecology, JIE</i>	2.446	1997	278	12
<i>Environmental Science and Technology, ES&T</i>	4.827	1967	251	9
		Total	2,030	142

of this study is to determine the characteristics of papers published on LCA by Spanish researchers in four select scientific journals and perform a comparative analysis with articles published by authors of other nationalities. Our study aims to discover the evolution in time of the number of articles published by Spanish researchers, the main research topics addressed in these articles, the main similarities and differences that may exist between the Spanish and overall situations, and finally also some of the features of the Spanish authors, such as the type of companies or institutions to which they belong.

Taking into account that Spain is at the forefront of countries in the number of ISO 14001 certificates issued [5], it is interesting to know if this interest in the management of environmental aspects tends to be reflected also in the use of LCA.

Methodology

The methodology applied here is based on prior studies that on the one hand have analyzed the LCA in other parts of the world and, on the other, those studies that have analyzed the other knowledge areas in Spain. Among the former, note should be taken of the study on the state of LCA in Australia published in 2009 under the title "Popularize or publish? Growth in Australia" [6]. Regarding the latter group, mention should be made, given its close relationship to LCA, of the report "La investigación sobre gestión medioambiental en la empresa en España (1993-2003)" (Research on environmental management in enterprises in Spain, 1993-2003) [7], although reference has also been made to other studies that address such diverse topics as quality management [8], operations management [9], and marketing [10].

Furthermore, there are numerous studies that have considered different aspects of LCA through literature reviews, albeit with somewhat different characteristics to those featured here, such as a review of the data published by firms in matters of environmental management [11, 12], a review of published case studies [13], and a review of papers on specific subjects, such as waste management or agriculture [14-16].

With a view to fulfilling goals, a study has first been conducted on the temporal trend in the number of papers on LCA published throughout the world in recent years. This

involved a search for papers that contain the phrases "life cycle assessment" or "life cycle analysis" in their title, abstract, or keywords, and have been published in any one of the journals listed in Table 1 between 1993 and 2010.

The journals have been chosen according to the following criteria: recognized international prestige, published in English, and with a significant impact factor. Given that the study aims to draw conclusion on the topics the papers address, those journals of a sectorial nature (forestry, chemicals, etc.) have been discarded, opting instead for those publications with a more general-interest approach within the fields of environmental management and sustainability. Finally, we understand that the fact the four journals chosen belong to different publishing groups provides the study with a certain degree of plurality.

Brief notes alluding to the presentation of books, congresses, or associations have been omitted as they cannot be fully considered scientific papers.

The consideration of papers as being by Spanish authors has been applied to those that feature at least one Spanish national among their authors.

The LCA in Spain

LCA as a Key Component of the European Union's Integrated Product Policy

Despite the limitations identified by many authors [17-27] the truth is that LCA also has a raft of virtues. Although there are other tools for the environmental enhancement of products, LCA is the only method that covers each one's full life cycle and makes systematic use of scientific knowledge on the environment [28]. Furthermore, as LCA is also considered to be the most complete environmental assessment tool in the field of eco-design [29], it can help to transform the way we perceive and undertake economic activities [30] and, moreover, it has the advantage of being backed by international standards [31-35].

Today, industries use LCA to compare alternatives in product development, in sales to report on a product's environmental performance, and as a tool in the decision-making process involved in environmental management. For their part, governments use LCA to analyze alternatives in diverse social systems, such a waste management operations, and as a pillar of integrated product policy, in eco-

labeling systems, and in green public procurement [24]. Indeed, LCA received a boost from the institutions in Europe in February 2001, when the European Commission published its Green Paper on Integrated Product Policy [36].

The concept “Integrated Product Policy” was coined in the 1990s, being the first conceptual research on the topic in the EU a project funded by the EU DGXII, within the program “Environment and Climate” [37, 38]. Subsequently, other studies conducted by Ernst and Young, together with the Science and Policy Research Unit at Sussex University, on behalf of the DG Environment, would provide the following definition of IPP: “Public policy that explicitly aims to modify and improve the environmental performance of product systems” [39].

LCA is recognized within the context of IPP as “the best framework for assessing the potential environmental impacts of products currently available” [40]. Furthermore, one of the four approaches proposed by the commission is “business leadership in greener production.” The commission considers the improvement in information to be a key mechanism for disseminating an eco-friendly culture in the business world, and thereby stipulates that the application of LCA should be promoted as a support tool [37].

Rubik and Scholl in their study “Integrated Product Policy in Europe – a development model and some impressions,” published in 2002, compared the development of IPP in several EU countries and classified them according to the outcome. This study placed Spain amongst the weaker performers, together with countries such as Ireland, Luxemburg, and Portugal, whereas countries such as the Netherlands, Denmark, Sweden, Finland, and the United Kingdom featured high up on the leader board. Although it is far from being the only tool for implementing IPP, there seems to be a clear need for LCA to be developed and embraced by Spanish companies and institutions if this is to be achieved.

LCA in Spain: Background

In Spain, the first serious steps of research into the Life Cycle Assessment were taken in Catalonia in the early 1990s by the hand of several lecturers and researchers at different Catalan universities. In fact, the first event in Spain at which topics related to LCA were addressed was the “Seminario Internacional Producto i embalatge” (International seminar on product and packaging) held in Sitges in June 1993 [41].

March 1995 witnessed the creation of the Spanish Association for Promoting the Development of Life Cycle Assessment (APRODACV in its Spanish acronym), the country’s first organization dedicated exclusively to LCA. This independent association, which attracts experts and organizations interested in LCA, has the mission to raise awareness and encourage the application of this methodology in Spain. Its members come from a wide range of fields, such as higher education, industry, consulting firms, and the administration [42].

An important milestone for APRODACV in particular, and for the development of LCA in Spain in general, was

undoubtedly the first workshop on LCA that was held in Barcelona under the name “LCA 2000” in November 1997, organized by APRODACV itself. It was attended by 60 experts in environmental matters from both the private and public sectors throughout Spain. The aim of the workshop was to share ideas, information, and experiences, but above all to identify the main actions and proposals with a view to implementing LCA as an environmental management tool by 2000 [43].

At that time, methodological concerns sparked the greatest interest, as LCA had not yet been fully developed. The next concern was to persuade the various agents, regional governments, universities and firms to embrace this methodology and implement schemes designed to marshal this development nationwide.

Over the following years, the arrangement of activities in the field of LCA increased significantly, as shown by the following events: Publication in 1997 of the book “Análisis de Ciclo de Vida” (Life Cycle Assessment), the first practical guide in Spanish for the application of LCA [40], in 2001 Madrid hosted the “SETAC Europe 11th Annual Meeting” [44], and in 2002 Barcelona held the “X SETAC Europe LCA Case Studies Symposium” [45]. Yet it is unquestionable that the following two initiatives helped this methodology to become definitively consolidated in Spain: In 2000, the *Red Catalana del Ciclo de Vida* (Catalan Network for Life Cycle Assessment) was created. Together with other public and private institutions, it involved almost all Catalan universities, although it was coordinated by the Autònoma University in Barcelona. Shortly afterward, 2002 witnessed the creation of the *Red Temática de Análisis de Ciclo de Vida* (Dedicated Network for Life Cycle Assessment), coordinated by the University of Santiago de Compostela, with the same objectives as its Catalan forerunner, albeit with a nationwide perspective [46]. The aims pursued by both these associations are to favor contact and the sharing of opinions and ideas between organizations, institutions, and businesses interested in understanding and applying LCA, and facilitating and boosting joint research amongst them. It is worth noting that these two associations were responsible for the organization in 2005 of the second international conference on life cycle management under the banner “LCM 2005 Innovation by Life Cycle Management” [47], which can be considered an unqualified success by Spanish experts in LCA.

Results and Discussion

Number of Publications

Given its dedicated nature, it is no surprise that the *International Journal of Life Cycle Assessment* has published half the papers considered for this study, while for its part, the *Journal of Cleaner Production* accounts for 22.5% of the papers, as can be seen in Table 1.

Of the 2,030 papers considered in the study, only 142 have at least one Spanish researcher listed among their authors, accounting for 7%. It is extremely difficult to objec-

Table 2. Issues discussed.

Categories	Total papers published		Papers with Spanish authors	
	Count	Percentage	Count	Percentage
Methodologies and other Developments	628	30.94%	16	11.27%
Agriculture, Fisheries, Food, Beverages, and Tobacco	238	11.72%	33	23.24%
Waste Management and Processing (Except water)	143	7.04%	9	6.34%
Chemical Sector and Plastics	106	5.22%	7	4.93%
Transport and Automotive	105	5.17%	4	2.82%
Building and Construction and Concrete	102	5.02%	13	9.15%
Electricity: Generation, Transport, Distribution, and Use	101	4.98%	5	3.52%
Biofuels	94	4.63%	4	2.82%
Water: Management, Treatment, and Use	76	3.74%	21	14.79%
Forestry and Paper Industry	70	3.45%	13	9.15%
Metal Manufacturing and Transformation	64	3.15%	0	0.00%
Packaging	33	1.63%	4	2.82%
Textiles and footwear	17	0.84%	3	2.11%
Others	253	12.46%	10	7.04%
Total	2,030		142	

tively appraise this figure on its own. (For comparative purposes, it should be considered that both Spain’s gross domestic product (GDP) and its population account for little more than 2% of the total for the industrialized nations.)

Below are presented some data from the global survey conducted by ISO in 2012 on the ISO 14001 certification that can help us better understand this data:

- In December 2012, Spain was the fourth country in the world, behind China, Japan and Italy, in number of issued certificates with 19,470, 6.81% of the total.
- In the same year Spain was also the second country in the world, behind China once again, in terms of number

of new certificates issued with 3,129, a 13.10% of total new certificates.

Fig. 1 shows the evolution over time of the number of papers published by Spanish authors and by the sum total of authors, without considering nationalities. We can see in Fig. 1 the growth of the total number of papers that occurred in the second half of the 1990s, probably due to the increase in scientific and coordination activities involving LCA that took place during that period worldwide [48]. The holding of numerous conferences and workshops on LCA, both in Europe and in the US, organized in the main by SETAC [49-55], the publication in 1993 of the first

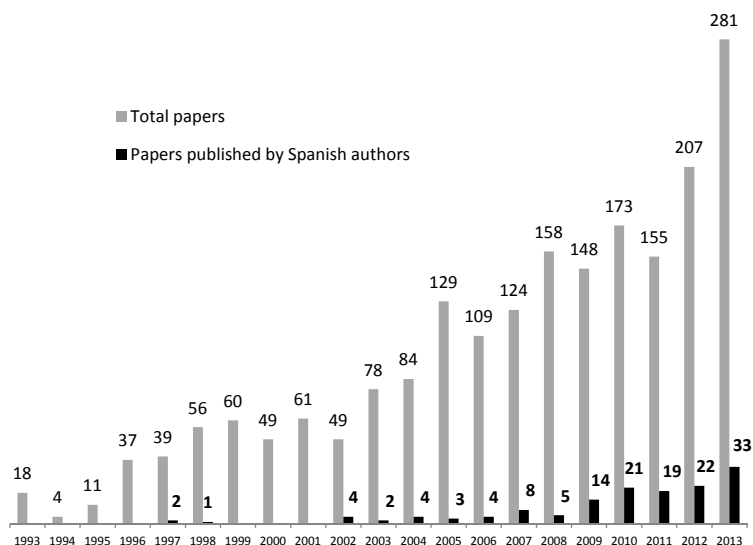


Fig. 1. Evolution in the number of papers.

methodological guide to LCA called “A Code of Practice” [56], and the approval of the ISO standards on LCA between 1997 and 2000 [31-34, 57].

For their part, the output by Spanish researchers in the first years of the study was limited to a handful of papers published in 1997 and 1998, with no publications whatsoever in 1999, 2000, and 2001. As of 2002, the number grew slowly until it finally took off in 2007. In fact, when only the 2007-13 period is considered, the percentage of papers with Spanish authors over the total amounts to almost 10%. One may assume that Spanish authors were encouraged to publish by the holding of the aforementioned conferences in Madrid in 2001 and in Barcelona in 2002 and 2005.

It is reasonable to suppose that this steady increase will be upheld over the coming years, although it is also logical to posit that after some years and as the methodology becomes more popular, the annual rate of publications will level off. In either case, given that the issue of climate change continues to be as topical as ever, LCA can be expected to maintain its validity and interest at least in the short to medium terms.

Topics Addressed in the Papers

When classifying the papers according to their subject matter, various options emerged, as there is no specific rule governing this matter. This is compounded by the fact that some papers deal with more than one topic, while others straddle the boundary between so-called methodological development and industrial applications. The final decision was to consider the categories as listed in Table 2.

The distribution of papers according to their subject matter is similar in both cases; the categories with the greater weight in the case of Spanish authors, and which overall account for 93% of the total, record a figure of 87% when all the publications are analyzed. The difference does not appear to be significant, quite the contrary, it is logical given that the dispersion of topics worldwide is greater due also to the higher number of papers.

On a global basis, the category “Methodologies and other Developments” is the one that has aroused the greatest interest among researchers, with almost 31% of the papers. This is a situation that applies at first to almost all disciplines, and it is to be expected that over the coming years its share will drop, while the papers based on the application of those developments will increase sharply. Next up, although a long way behind methodological developments, are the categories that a priori are to be expected considering the possibilities provided by LCA: with almost 12% there is “Agriculture, Food, Beverages, and Tobacco,” standing in second place, followed by “Waste Management,” which accounts for slightly more than 7%. Finally, these categories are followed, although with somewhat lesser intensity, by papers dealing with the chemical sector and plastics, transport, energy in its various forms, building, metal manufacturing and transformation, forestry and the paper industry, and water and its treatment.

In turn, the topics most covered by Spanish researchers, besides methodological aspects, have been those focusing

on agriculture and food, water, forestry and paper, building, waste management, the chemical sector, and energy.

A comparison of the distributions recorded in each case throws up the following results: The category “Methodologies and other Developments,” while still in fifth place in terms of the number of publications, does not have as much specific weight in the case of Spanish authors. In fact, it accounts for only slightly over 11%, far from the 31% mentioned for the sum total of papers. This discrepancy may be due to the time lag. On a global basis, papers first began to be published between 1993 and 2000, whereas the publications by Spanish authors started to appear mainly as of 2002, when the tool had become more mature and research focused more on its applications.

The papers that address all matters related to the management of water account for 14.79% in Spain, as opposed to 3.74% worldwide. This figure appears to reflect the huge importance that management of this extremely scarce resource has for Spain. When it is considered that the main countries developing this methodology, besides the United States, have been mainly northern European countries such as Sweden, Norway, and Denmark, as well as Germany and Switzerland, it is easy to understand this disparity, as these countries have far greater natural water resources than Spain.

Although as we shall see in due course, firms do not rank among the major publishing actors on LCA, the reality of Spain’s business fabric appears to have a major bearing on the topics chosen by researchers. It does not seem to be a coincidence that certain economic sectors of special significance in Spain are studied by Spanish researchers to a greater extent than their peers throughout the world:

- The number of papers addressing topics related to agriculture, fisheries, and food reflects the importance the primary sector still has today in the Spanish economy. While on a global scale the percentage of papers that address this subject matter, although still significant, does not reach 12%, Spanish researchers have considered it in just over 23% of their papers.
- Topics related to forestry and the paper industries also feature more prominently among the papers by Spanish authors, with slightly more than 9%, as opposed to 3.45% worldwide.
- Although to a lesser extent, the same can be said about building and construction, where 9.15% of the papers with Spanish authors have studied this sector as opposed to 5% of the sum total of articles.

Also, recording relatively significant percentages that are similar in both distributions are the chemical sector and energy matters, which are also activities in which there are major Spanish corporations (Endesa, Iberdrola, Repsol etc). In turn, other topics that have certain significance in the overall sum of papers, such as biofuels or the metal sector, feature less or even not at all in the papers published by Spanish authors.

There is an apparent link between the most frequently addressed topics and the geographical areas in Spain that are most active in LCA. As already noted, the *Red Temática de Análisis de Ciclo de Vida* (Dedicated Network for Life

Table 3. Some facts about the authors.

Papers with only Spanish authors	75	52.82%
Papers with Spanish and authors of other nationalities	67	47.18%
Total number of articles with at least one Spanish author	142	100%
Spanish authors	185	55.55%
Authors of other nationalities	148	44.45%
Total number of authors	333	100%
Spanish authors affiliated with a university	129	69.7%
Spanish authors affiliated with public and private organisations and associations	41	22.2%
Spanish authors affiliated with business	15	8.1%
Total number of Spanish authors	185	100%

Cycle Assessment) and the *Red Catalana del Ciclo de Vida* (Catalan Network for Life Cycle Assessment) are coordinated, respectively, by the University of Santiago de Compostela in Galicia and the Aut3noma University in Barcelona in Catalonia. Indeed, the economic activities prevailing in both regions are reflected in the classification:

- The importance of the category “Forestry and the Paper Industry” appears to respond to the major presence this sector has in Galicia and, moreover, the papers on this subject matter have been penned mostly by researchers at the University of Santiago de Compostela.
- Regarding Catalonia, two topic areas have been singled out that are related to geographical location: on the one hand, the category related to agriculture and food gives rise to several studies on agriculture and the use of greenhouses in the Mediterranean, among others. On the other hand, the category “Chemical Sector and Plastics” appears well positioned in the ranking, probably due to the importance of the chemical cluster in Tarragona, involving some of the sector’s largest corporations, such as Dow and BASF, amongst others.

Authors and their Affiliation

The study of the authors has considered solely the 142 papers that included at least one Spanish researcher. As can be seen in Table 3, almost 53% of them are the work of Spanish authors alone, while the rest have at least one other author of a different nationality.

The total number of researchers involved in the drafting of these 142 papers analyzed amounts to 333, of whom 185 are Spanish, with the remaining 148 being non-nationals, as shown in Table 3.

Given that a large share of the authors are involved in writing more than one paper, the sum total of authors amounts to 637, which gives an average of 4.82 authors per paper. It has been confirmed that, in general, the various authors of the same paper are also attached to different organizations, which reflects a trend towards cooperative

work and networking, a very positive approach in research work. Along these same lines, a further positive aspect is that 47% of the papers analyzed have been produced jointly by authors of different nationalities.

Specifically concerning the organizations to which the authors are attached, the figures in Table 3 are quite eloquent: most of the authors, 129, which is almost 70%, belong to the world of higher education, 41 of them are employed in sundry public organizations, sectorial associations, and public and private research centers, and only the remaining 15 work within the corporate sector.

Does this mean that firms are either unaware of or do not sufficiently use LCA methodology? Not necessarily, as some authors contend that the instances of research conducted within firms rarely end up being published. In fact, in 1996 Hunt and Franklin reported that only a few of the approximately 200 REPA studies conducted by firms had been published [58]. Some years later, Mary A. Curran in her editorial “The Status of LCA in the USA” confirmed that although firms did use LCA internally, they were very cautious about disclosing their results in public fora [59].

Elsewhere, standard ISO 14044 places strict requirements on the public disclosure of those LCA studies that focus on the comparison of alternatives [60].

Nevertheless, and accepting that their low number means we should not draw definitive conclusions, it is worth describing some of the characteristics of the firms employing the researchers identified in this study. Firms providing environmental engineering and consulting services or those related to the management of water and urban wastes are the most numerous, accounting for five out of a total of 15. The few firms in the manufacturing sectors or of a more industrial nature, only 8 belong to the sectors of mining and building materials, forestry and different uses of wood, automotive, renewable energy sources, petrochemical, and food.

Finally, when checking the universities for which researchers are attached, the data are enlightening, with the Aut3noma University in Barcelona and the Polit3cnica University in Catalonia jointly accounting for 30% of the total number of authors, which makes Catalonia the Spanish region where LCA is being studied most extensively. All the other universities are a long way behind these two, although mention should be made of the University of Santiago de Compostela (Galicia), with over 10% of the total number of authors. It is worth mentioning that 22 private and public universities appear in the study and five authors are affiliated with foreign universities.

Conclusions

The first conclusion to draw from the study is that the publication of scientific articles on the LCA by Spanish authors runs parallel to that made by the whole set of researchers but with a lag of almost 10 years. While the take off in the total number of publications was produced by 1995, in Spain this did not happen until 2002. It is fair to clarify that a slight revision of the articles published in the early years of this study reveals that most of the authors

belong to leading LCA countries from northern Europe and North America, so the detected lag is actually about these countries.

As for the topics discussed, except the already mentioned differences on water management or forest industry, among others, the topics of greatest interest to Spanish researchers are very similar to those chosen by the international community. In this regard it would be interesting to conduct a similar study considering sectorial journals on agriculture, forest industry, or waste management, to name but a few.

Another conclusion from the study is the apparent lack of interest shown by the Spanish business community so far in publishing their experiences on LCA in such journals. The results reveal that only a few firms, mostly within the field of environmental consulting and guidance, are disclosing their experiences in the application of this methodology. However, one must take into account, as has been said, that some companies that perform LCA studies have decided not to make them public, or do so in sectorial journals and conferences where they contact with customers, suppliers, and other agents with whom they interact in their markets.

It is to be expected that, in response to the need to boost the imperatives of sustainable development, interest will grow as regional legislation and public policies steadily include the requirement to conduct LCA studies for different products and processes. Indeed, LCA studies are now an essential requirement for the award of certain ecodesign certificates [61], environmental product declarations (EPDs), and ecolabels [62-65]. Given the positive reception afforded in Spain to other certifiable approaches, such as those related to quality management systems and the environment [66], it is to be hoped that in time firms will opt for the path of certification in the field of LCA.

This hope seems to be reflected in the fact that when considering only the period 2007-13, 10% of the total of items identified in the study contains Spanish authors in line with data from the survey of ISO mentioned above [5] that new ISO 14001 certificates in Spain represented 13.10 per cent of the total in 2012.

This research is intended to be a first step toward understanding the situation of LCA methodology in Spain. New research on this matter should permit us to ascertain the true state of this methodology among companies. This new study should draw conclusions on the objectives pursued by LCA users, the main obstacles involved, and highlight the advantages firms gain through its use. Studies of this nature have already been conducted in other countries or regions, mainly in northern Europe, although also in the U.S. and Japan [67-72], and they could also be used for comparing the situation in terms of LCA between Spanish firms and those in other countries.

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