THE ENVIRONMENTAL MANAGEMENT SYSTEMS AS A TOOL FOR INTEGRATING THE PRINCIPLES OF THE CIRCULAR ECONOMY WITHIN MANUFACTURING FIRMS

Alexandra Barón Dorado

DOCTORAL THESIS

THE ENVIRONMENTAL MANAGEMENT SYSTEMS AS A TOOL FOR INTEGRATING THE PRINCIPLES OF THE CIRCULAR ECONOMY WITHIN MANUFACTURING FIRMS

ALEXANDRA BARÓN DORADO

2023

DOCTORAL THESIS

THE ENVIRONMENTAL MANAGEMENT SYSTEMS AS A TOOL FOR INTEGRATING THE PRINCIPLES OF THE CIRCULAR ECONOMY WITHIN MANUFACTURING FIRMS

Alexandra Barón Dorado

2023

Universitat de Girona

DOCTORAL THESIS

THE ENVIRONMENTAL MANAGEMENT SYSTEMS AS A TOOL FOR INTEGRATING THE PRINCIPLES OF THE CIRCULAR ECONOMY WITHIN MANUFACTURING FIRMS

ALEXANDRA BARÓN DORADO

2023

DOCTORAL PROGRAMME IN LAW,
ECONOMICS AND BUSINESS

Director: Rodolfo de Castro Vila, PhD

Co-Director: Gerusa Giménez Leal, PhD

A thesis submitted on fulfilment of the requirements for the deegre of Doctor by the University of Girona with International Doctor Mention

Rodolfo de Castro Vila (PhD) and Gerusa Giménez Leal (PhD) from the departament of Business Administration and Product Design of the University of Girona

CERTIFY

That Alexandra Barón Dorado carried out the dissertation entitled "The environmental management systems as a tool for integrating the principles of the circular economy within manufacturing firms", under our supervision and that it fulfils the requirements for the degree of Doctor by the University of Girona with International Doctor Mention.

Therefore, we sign the present certificate.

Rodolfo de Castro Vila, PhD	Gerusa Giménez Leal, PhD
Director	Co-Director

Girona, March 2023

Universitat de Girona

Rodolfo de Castro Vila (PhD) and **Gerusa Giménez Leal** (PhD) as co-authors of the following articles:

- Barón Dorado, A., Giménez Leal, G., de Castro Vila, R. (2022). "Environmental policy and corporate sustainability: The mediating role of environmental management systems in circular economy adoption" **published** in the journal Corporate Social Responsability and Environmental Mangement, 1–13. https://doi.org/10.1002/csr.2238

- Barón, A., de Castro, R., Giménez, G. (2020). "Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain" **published** in the journal Sustainability, 12, 1–28. https://doi.org/10.3390/su12219011

- Barón Dorado, A., Giménez Leal, G., de Castro Vila, R. (2022). "EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy" **published** in the Journal of the Cleaner Production. http://10.1016/j.jclepro.2022.133213

We accept that Mrs. Alexandra Barón Dorado presents the articles cited as the main autor and as part of her doctoral thesis. The article cannot, therefore, form part of any other doctoral thesis.

For all intents and purposes, we sign the present certificate.

Rodolfo de Castro Vila, PhD
Co-author

Gerusa Giménez Leal, PhD
Co-author

Girona, March 2023

Universitat
de Girona

Paul E.M. Ligthart (PhD) and **Sjors Witjes** (PhD), as co-authors of the following article:

- Barón Dorado, A., Ligthart, P.E.M., Witjes, S. (2022). Practising more Circular Economy: enabling configurations of tecnologies and managerial practices in the manufacturing industry" **submitted** to Journal of Resources, Conservation & Recycling.

We accept that Mrs. Alexandra Barón Dorado presents the article cited as the main author and as part of her doctoral thesis. The article cannot, therefore, form part of any other doctoral thesis.

For all intents and purposes, we sign the present certificate.

LIST OF PUBLICATIONS DERIVED FROM THE DOCTORAL THESIS

This doctoral thesis, entitled '**The environmental management systems as a tool for integrating the principles of the circular economy within manufacturing firms'**, is a compendium of publications compresing four articles following the same research line. These publications have been previously accepted or sent to the respective journals and their quality indexes are indicated below.

Article 1: Published

Title: Environmental policy and corporate sustainability: The mediating role of environmental management systems in circular economy adoption

Authors: Barón Dorado, A., Giménez Leal, G., de Castro Vila, R.

Journal: Corporate Social Responsability and Environmental Mangement

JCR (2020): Impact Factor: 8.741. Quartile: Q1 (Environmental Studies) (Ranking 8/125).

SCOPUS (2021): Impact Factor: 1.945. Quartile: Q1 (Environmental Science). H Index: 82

Acceptance date: 26 December 2021

Article 2: Published

Title: Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain

Authors: Barón, A., de Castro, R., Giménez, G.

Journal: Sustainability

JCR (2020): Impact Factor: 3.251. Quartile: Q2 (Environmental Studies) (Ranking 59/125).

SCOPUS (2020): Impact Factor: 0.612. Quartile: Q2 (Environmental Science). H Index: 109

Acceptance date: 20 October 2020

Article 3: Published

Title: EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy

Authors: Barón Dorado, A., Giménez Leal, G., de Castro Vila, R.

Journal: Journal of the Cleaner Production

JCR (2020): Impact Factor: 9.297. Quartile: Q1 (Environmental Sciences) (Ranking 18/274).

SCOPUS (2021): Impact Factor: 1.921. Quartile: Q1 (Environmental Science). H Index: 232

Acceptance date: 16 July 2022

Article 4: Submitted

Title: Practising more Circular Economy: enabling configurations of technological and managerial practices in the manufacturing industry

Authors: Barón Dorado, A., Ligthart, P.E.M., Witjes, S.

Journal: Resources Conservation and Recycling

JCR (2020): Impact Factor: 10.204. Quartile: Q1 (Environmental Sciences) (Ranking 11/274).

SCOPUS (2021): Impact Factor: 2.589. Quartile: Q1 (Economics and Econometrics). H Index: 150

Submittion date: 9 December 2022

OTHER PUBLICATIONS RELATED TO THE DOCTORAL THESIS

In addition to the journal publications, the research carried out provided the book chapters listed below:

Proceedings of the 15th International Conference on Industrial Engineering and Industrial Management and XXV Congreso de Ingeniería de Organización

Exploring the relationship between Environmental Management Systems and Circular Economy adoption

https://dx.doi.org/10.5281/zenodo.5109480

Status: Published

LIST OF CONFERENCE, COLLOQUIUMS AND WORKSHOPS

Besides the preceeding publications, the research carried out provided other outcomes presented in the varius conferences listed below.

14th International Conference on Industrial Engineering and Industrial Management

XXIV Congreso de Ingeniería de Organización (CIO) 2020

Presentation: Adopción de prácticas e iniciativas de Economía Circular en organizaciones registradas EMAS. El caso España.

Madrid (Spain), 9th –10th July 2020

15th International Conference on Industrial Engineering and Industrial Management

XXV Congreso de Ingeniería de Organización (CIO) 2021

Presentation: Exploring the relationship between Environmental Management Systems and Circular Economy adoption.

Burgos (Spain), 8th –9th July 2021

16th International Conference on Industrial Engineering and Industrial Management

XXVI Congreso de Ingeniería de Organización (CIO) 2022

Presentation: Assesing environmental statements as a circular performance indicators

Toledo (Spain), 8th –9th July 2022

RESEARCH STAY

During the period of this thesis the following research stay was made:

Radboud University (The Netherlands)

Institute / Departament: Institute for Management Research / Business Administration

Supervisors during the research stay: Professors Paul Ligthart and Sjors Witjes

Stay: 3 months from 4th of September to the 6th of December of 2021 (92 days)

Scholarship: IF MOB UdG2021

Poznan University of Technology (Poland)

Faculty of Engineering Management

Summer School: Agile Management in Industry 4.0

Stay: 2 weeks, 19th to 30th of September of 2022

Scholarship: NAWA PROM2022

"Great things do not just happen by impulse, but as a succession of small things linked together"

Vincent Van Gogh

Acknowledgments

La frase de Vincent Van Gogh con la que abre esta tesis, es una reflexión que siempre me ha gustado y que también me recuerda el discurso que dio Steave Jobs a los graduados de la universidad de Stanford en el 2005. La idea sobre como muchos de nuestros aprendizajes y experiencias que parecen aleatorios, solo con el tiempo podemos distinguir la línea que traza la conexión entre ellos. Algo así como una serendipia de sucesos, el orden que un punto sigue a otro a pesar de existir todo un mundo de posibilidades. Y es en esta reflexión que siento un enorme agradecimiento, porque de todas distintas posibilidades que tenia para escoger una carrera, todos los ires y venires para no desistir de mi idea de hacer un master y finalmente llegar a ser candidata doctoral, no podía haber un mejor camino que me trajera hasta aquí. Quizás alguno más rápido, o quizás uno más fácil, pero no mejor. Y la prueba de ello son las personas que me han acompañado durante este camino. Mi lista inicia primero con mis directores de tesis, Rudi y Gerusa, no podría haber tenido mejores directores de tesis que vosotros dos, gracias por haberme aceptado como su doctoranda y por todas las enseñanzas y orientación durante estos casi 4 años. Por todo el compromiso, dedicación y disponibilidad que siempre mostraron hacia mi, y además de la excelencia profesional, por la increíble parte humana, que creedme, una sonrisa y una palabra de ánimo en los momentos exigentes del doctorado, valen oro y marcan la diferencia. A vosotros siempre agradecida.

A Andrea Bilkfalvi que desde cuando hice el master y le conté sobre mi interés por la investigación y hacer un doctorado, me motivo a hacerlo y durante todo este tiempo he recibido su apoyo y soporte incondicional. A los profesores Paul y Sjors, gracias por acogerme durante la estancia de investigación y todo lo que me habéis enseñado sobre investigación, debate y pensamiento crítico, así como las recomendaciones turísticas por Holanda, y como no, las Bosche bols. También a todos los profesores y personal del departamento, Manel, Fernando, Xavi, Fausto, Lluis, Sussi, Josep, Martí, Montse, gracias por la buena energía que siempre tenéis, así como por vuestros consejos y apoyo. ¡OGEDP no sería lo mismo sin vosotros! También un especial agradecimiento para mis compañeros: Giovanna, Victor, Prassana, Jackelin, Jana, y a Dalilis, porque además de ser mi amiga, fue algo así como mi 'tutora madrina' con tus consejos para la tesis. A vosotros

mil gracias por todo el soporte, la compañía en momentos duros, cariño, alegrías y batallas compartidas.

A mi familia y amigos, a mis Padres, todo esto es por vosotros y para vosotros, gracias por haberme enseñado a creer en mi, a trabajar por los sueños, a no rendirme e insistir en los propósitos. Tambien a Jenny, Cami, Nico, Jaime, tia Hine, abue Isabel y a la tia Dora, gracias por haberme inculcado el amor por la lectura y mostrarme el poder de la educación siempre desde tu ejemplo. A mis amigos, que siempre estan a mi lado y me impulsan a continuar: Eli, Steaven, Corinna, Joan, Gaz, Angy, Camilo y en especial a Dianita y Karen. Gracias a vosotras porque incluso en la distancia estuvisteis a mi lado, vosotras no dudasteis ni un momento en que podía hacer esto y me animaisteis a ir a por más.

Esto no hubiera ocurrido sin vosotros. Los logros y éxitos siempre son mejores cuando son compartidos. Gracias por el tiempo, disposición, sonrisas y por haber estado a mi costado compartiendo esta etapa de mi camino.

Doctoral Dissertation framed within the reference project GRHCS069 "Grup de Recerca Avançada sobre Dinàmica Empresarial i Impacte de las Noves Tecnologies a les Organitzacions (GRADIENT)", in wich the candidate is a researcher and within the programme "Ajuts per a la contratació d'investigadors en Formació (IFUdG2019)" financed by the University of Girona as a part of the R&D projects aid programme.

Table of Contents

List of Figures

List of Tables

Table of Abbreviations

CE	Circular Economy
CDP	Carbon Disclosure Project
BSI	British Standards Institute
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
EC	European Commission
GRI	Global Report Initiative
ISO	International Organization for Standardization
KPI	Key Performance Indicators
LE	Large Enterprises
LR	Literature Review
OCR	Optical Character Recognition
QCA	Qualitative Comparative Analysis
SME	Small and Medium Enterprises
UL	Underwriters Laboratories Standards
VRO	Value Retention Options
WEF	World Economic Forum
WBCSD	World Business Council for Sustainable Development

Abstract (ENG)

This thesis analyses the contribution of Environmental Management Systems (EMS)'s in adopting Circular Economy (CE) principles in manufacturing companies. It explores different aspects such as the reporting and communication of environmental performance, the adoption of circularity Key Performance Indicators (KPIs), as well as the possible configurations of organisational and technological practices focused on CE and, consequently, the role played by EMS in such configurations.

The dissertation is based on a mixed empirical methodology using, on the one hand, the environmental statements of companies with EMAS registration at a regional and national level and, on the other hand, the European Manufacturing Survey 2018 with two sub-samples from Spain and The Netherlands. Thus, noteworthy results were obtained that answered the research questions posed. Firstly, out of a sample of 85 companies, a positive relationship was found between companies that had implemented an EMS and a greater intensity in circularity practices. Secondly, from the two studies that used data from the EMAS environmental declarations, the practices reported by the 31 sites at the regional level (Catalonia) and the 122 sites at the national level in Spain were observed. The national study also analysed the quantitative information within the declarations to check the possibilities of using circularity indicators with the information that companies share in their environmental reports. Seventeen CE practices mentioned by the companies were detected, but only three provided quantitative information applicable to adopting circularity KPIs.

Thirdly, and under the lens of 'Configuration of Practices', 288 manufacturing companies were analysed, and the relationship of different organisational and technological practices focused on CE based on academic literature. We obtained 25 consistent configurations that promote greater circularity according to each production stage.

According to the results, it can be concluded that EMS contribute to the transition towards more circular production processes in manufacturing companies. However, in order for EMSs to be efficient tools in the integration of CE principles, the results of this thesis emphasize paying more attention to crucial aspects such as management and organisational commitment, periodic review and verification of results, and communication of environmental performance. Preferably with quantifiable data that allow the inclusion of circularity actions within the framework of continuous improvement.

Keywords: Circular Economy; Environmental Management Systems; Manufacturing; Production; Circularity practices; Organisational practices; Circularity indicators; Environmental reporting; Configurations.

Resumen (ES)

Esta tesis analiza la contribución de los Sistemas de Gestión Ambiental (SGA) en la adopción de principios de Economía Circular (EC) en empresas manufactureras. Explora distintos aspectos como el reporte y comunicación del comportamiento ambiental, la adopción de Indicadores Clave de Desempeño (KPIs) de circularidad, así como las posibles configuraciones de prácticas organizativas y tecnológicas enfocadas en EC y, por consiguiente, el rol que desempeñan los SGA en dichas configuraciones.

La disertación se basa en una metodología mixta empírica utilizando, por un lado, las declaraciones ambientales de empresas con registro EMAS a nivel autonómico y nacional en España, y por otro, la Encuesta Europea de Manufactura 2018 con dos sub-muestras de España y Países Bajos. Así, se obtuvieron resultados significativos que respondían a las preguntas de investigación planteadas. En primer lugar, de una muestra de 85 empresas, se encontró una relación positiva entre las empresas que habían implementado un SGA y una mayor intensidad en prácticas de circularidad. En segundo lugar, de los dos estudios que utilizaron datos de las declaraciones ambientales EMAS, se observaron las prácticas reportadas tanto de los 31 centros a nivel autonómico (Cataluña), como de los 122 centros a nivel nacional en España. En el estudio nacional también se analizó la información cuantitativa dentro las declaraciones para comprobar las posibilidades del uso de indicadores de circularidad con la información que las empresas comparten en sus reportes ambientales. Se detectaron 17 prácticas de EC mencionadas por las empresas, pero solo en 3 prácticas se suministraba información cuantitativa aplicable en la adopción de KPIs de circularidad.

En tercer lugar, y bajo el lente de 'Configuración de Prácticas' se analizaron 288 empresas manufactureras y la relación de distintas prácticas organizativas y tecnológicas enfocadas en EC basados en la literatura académica. Se obtuvieron 25 configuraciones consistentes que promueven una mayor circularidad en cada etapa de producción.

De acuerdo con los resultados, se puede concluir que los sistemas de gestión ambiental contribuyen en la transición hacia procesos de producción más circulares en empresas dedicadas a la manufactura. Sin embargo, para que los SGA puedan ser herramientas eficientes en la integración de principios de EC se enfatiza en la necesidad de su implementación a partir del compromiso gerencial y organizativo reflejado en la política ambiental, en la revisión y verificación periódica de resultados y en la comunicación de su comportamiento ambiental, preferiblemente con datos cuantificables que permitan incluir las acciones de circularidad dentro del marco de la mejora continua.

Palabras clave: Economía Circular; Sistemas de Gestión Ambiental; Manufactura; Producción; Prácticas de circularidad; Prácticas organizativas; Indicadores de circularidad; Reporte ambiental; configuraciones.

Resum (CAT)

Aquesta tesi analitza la contribució dels Sistemes de Gestió Ambiental (SGA) en l'adopció de principis d'Economia Circular (EC) a les empreses manufactureres. Explora diferents aspectes com la manera de reportar i comunicar el comportament ambiental, l'adopció de KPI's de circularitat, així com les possibles configuracions de pràctiques organitzatives i tecnològiques enfocades a l'EC i, en conseqüència, el rol que exerceixen els SGA en aquestes configuracions.

La dissertació es basa en una metodologia mixta empírica utilitzant, d'una banda, les declaracions ambientals d'empreses amb registre EMAS a nivell autonòmic i nacional a Espanya, i per l'altra, l'Enquesta Europea de Manufactura 2018 amb dues sub-mostres d'Espanya i Països Baixos. Així, es van obtenir resultats significatius que responien a les preguntes de recerca plantejades. En primer lloc, d'una mostra de 85 empreses, es va trobar una relació positiva entre les empreses que havien implementat un Sistemes de Gestió Ambiental i una major intensitat en pràctiques de circularitat. En segon lloc, dels dos estudis que van utilitzar dades de les declaracions ambientals EMAS, es van observar les pràctiques reportades tant dels 31 centres a nivell autonòmic (Catalunya), com dels 122 centres a nivell nacional a Espanya. En l'estudi nacional també es va analitzar la informació quantitativa dins les declaracions per a comprovar les possibilitats de l'ús d'indicadors de circularitat amb la informació que les empreses comparteixen en els seus informes ambientals. Es van detectar 17 EC pràctiques esmenades per les empreses, però només en 3 pràctiques es subministrava informació quantitativa aplicable en l'adopció de KPI's de circularitat.

En tercer lloc, i sota la lent de 'Configuració de pràctiques', es van analitzar 288 empreses manufactureres i la relació de diferents pràctiques organitzatives i tecnologies enfocades en EC prenent com a referència la literatura acadèmica. Es van obtenir 25 configuracions consistents que promouen una major circularitat en cada etapa de producció.

D'acord amb els resultats, es pot concloure que els sistemes de gestió ambiental contribueixen en la transició cap a processos de producció més circulars en empreses dedicades a la fabricació. No obstant això, perquè els SGA puguin ser eines eficients en la integració de principis d'EC emfatitza en la necessitat de la seva implementació a partir del compromís gerencial i organitzatiu reflectit en la política ambiental, a la revisió i verificació periòdica de resultats i a la comunicació del seu comportament ambiental, preferiblement amb dades quantificables que permeten incloure les accions de circularitat dins del marc de la millora contínua.

Paraulas clau:
Economia Circular; Sistemes de Gestió Ambiental; Fabricaciò; Producció; Pràctiques de circularitat; Pràctiques organitzatives; Indicadors de circularitat; Reporti ambiental: Configuracions.

Zusammenfassung (GER)

In dieser Doktorarbeit wird der Beitrag von Umweltmanagementsystemen (UMS) zur Einführung von Grundsätzen der Kreislaufwirtschaft (CE) in Produktionsunternehmen untersucht. Sie untersucht verschiedene Aspekte wie die Berichterstattung und Kommunikation der Umweltleistung, die Einführung von Kreislaufwirtschafts-Schlüsselkennzahlen (KPI) sowie die möglichen Konfigurationen von organisatorischen und technologischen Praktiken, die auf die Kreislaufwirtschaft ausgerichtet sind, und folglich die Rolle, die UMS in solchen Konfigurationen spielt.

Die Dissertation gründet sich auf eine gemischte empirische Methodik, bei der zum einen Umwelterklärungen von Unternehmen mit EMAS-Eintragung auf regionaler und nationaler Ebene in Spanien und zum anderen die Europäische Erhebung über das verarbeitende Gewerbe 2018 mit zwei Teilstichproben aus Spanien und den Niederlanden verwendet werden. Auf diese Weise wurden signifikante Ergebnisse erzielt, die die gestellten Forschungsfragen beantworten. Erstens wurde bei einer Stichprobe von 85 Unternehmen ein positiver Zusammenhang zwischen Unternehmen, die ein UMS eingeführt hatten, und einer höheren Intensität von Kreislaufwirtschaftspraktiken festgestellt. Zweitens wurden in den beiden Studien, die Daten aus den EMAS-Umwelterklärungen verwendeten, die gemeldeten Praktiken sowohl der 31 Zentren auf regionaler Ebene (Katalonien) als auch der 122 Zentren auf nationaler Ebene in Spanien untersucht. Die nationale Studie analysierte auch die quantitativen Informationen in den Erklärungen, um die Möglichkeiten der Verwendung von Kreislaufwirtschaftsschlüsselkennzahlen mit den Informationen zu prüfen, die Unternehmen in ihren Umweltberichten veröffentlichen. Es wurden siebzehn von Unternehmen erwähnte CE-Praktiken ermittelt, aber nur 3 Praktiken lieferten quantitative Informationen, die für die Einführung von Kreislaufwirtschafts-KPI anwendbar sind.

Drittens wurden 288 Unternehmen des verarbeitenden Gewerbes unter dem Gesichtspunkt der "Praxiskonfiguration" analysiert und die Beziehung zwischen den verschiedenen organisatorischen und technologischen Praktiken auf der Grundlage der wissenschaftlichen Literatur auf CE konzentriert. Es wurden fünfundzwanzig konsistente Konfigurationen ermittelt, die eine größere Kreislauffähigkeit auf jeder Produktionsstufe fördern.

Die Ergebnisse lassen den Schluss zu, dass Umweltmanagementsysteme zum Übergang zu stärker kreislauforientierten Produktionsprozessen in Fertigungsunternehmen beitragen. Damit UMS jedoch wirksame Instrumente für die Einbeziehung von CE-Grundsätzen sind, muss ihre Umsetzung auf der Grundlage des Engagements des Managements und der Organisation erfolgen, das sich in der Umweltpolitik, in der regelmäßigen Überprüfung und Begutachtung der Ergebnisse und in der Mitteilung der Umweltleistung widerspiegelt, vorzugsweise mit quantifizierbaren Daten, die die Einbeziehung von Maßnahmen zur CE im Rahmen einer kontinuierlichen Verbesserung ermöglichen.

Schlüsselwörter: Kreislaufwirtschaft; Umweltmanagementsysteme; Fertigung; Produktion; Praktiken der Kreislaufwirtschaft; Organisatorische Praktiken; Indikatoren der Kreislaufwirtschaft; Umweltberichterstattung; Konfigurationen.

Chapter 1. Introduction

"Normality is a paved road: It's comfortable to walk,
but no flowers grow on it"
Vincent Van Gogh

1.1 Circular Economy: the pathway for sustainable development

Since the beginning of the century, the planetary problems of increasing production and demand, the scarcity of raw materials and the effects of the increase in greenhouse gases have become more evident. The term sustainability was first mentioned in 1987 in the Brundtland report "Our Common Future", defining it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".(Brundtland et al., 1987). In 1987, at the Rio Summit, the objectives of sustainable development were established, and the concept itself began to take on greater relevance, including it at different levels of society. Thus, political and organisational entities are trying, through agendas such as Agenda 21, the Kyoto Protocol, the Paris Agreement and the Glasgow Climate Pact, to establish goals for reducing the impact of greenhouse gas production.

Goal 12, related to sustainable production, has been taken as a relevant axis in different fields of industry and manufacturing companies. Different practices and systems started to be applied to align with this goal. The creation of Environmental Management Systems (EMS), green product certificates, implementation of environmental indicators, accounting of their environmental performance and product life cycle analysis are some of the tools used mainly by companies from different sectors around the world. However, despite the implementation of these tools, their results and effects are still insufficient concerning the objectives set within the sustainability agenda.

The linear economy has been highly successful in generating material wealth in the industrial nations up to the 20th century (Sariatli, 2017), in which raw materials are extracted, transformed, used by consumers, and discarded at the end of their life cycle. The problem with this system is both in the input and output, that is, in the high quantities of raw material extraction to meet demand, as well as in the high volume of waste that reaches incinerators or landfills even though it is still in a usable condition. On the other hand, waste management costs remain high for both companies and regional administrations, and the loss of value does not allow waste to be reused or reintroduced into the system.

Making a change of production model and, in this case, also societal, where it requires not only a change of perspective of the producer but also and mainly of the consumer, requires great transition efforts. As mentioned Chick & Meleis (1986) the transition conceptualized as "two points of relative stability with movement in between" is generally associated with change. However, although "change is inherent in all transitions, not all changes are transitions" (Meleis et al., 2000). Therefore, transitions should be understood as a set of processes associated with time and movement, which require facilitating and inhibiting conditions for them to occur (Willson, 2019).

Therefore, the transition to a new model comprises various aspects and nuances that make it challenging to approach it holistically and require the intervention and understanding of the small parts that converge. It is also essential to know the starting point and current status to define the direction of the transformation more clearly. It is convenient to consider the tools used so far and to delve deeper into those that have been beneficial or have allowed progress towards the proposed objectives. As mentioned by van Eijk (2015) "the transition to the Circular Economy (CE) requires a systemic approach that uses the broad set of policy tools and measures, across different points of value change and affecting the full set of stakeholders and public parties".

Marrucci et al. (2019) identified a set of tools as circularity drivers, such as, for example, Energy Labeling and Environmental Technology Verification (ETV), Ecodesign Directive, Eco-labeling, Green Public Procurement (GPP), and Environmental Management Systems (EMS), and points out the latter as the tool with the highest level of integration with CE and requiring further academic and technical discussion within the future research agenda. Therefore, this thesis seeks to contribute to the academic organisational literature by analysing EMS from their intrinsic characteristics, detecting which of them have the potential to streamline production and manufacturing companies to be more circular.

1.2 Research questions

This thesis then poses the following main research question:

Do EMS contribute to making manufacturing companies more circular?

In order to be able to answer this research question, this thesis takes two management systems into its analysis. The first one is the Eco-Management Audit Scheme (EMAS), mainly because of its character as a 'policy and measurement tool' as it is regulated by the European Commission, in addition to its characteristic of mandatory public reporting of environmental performance, objectives and annual achievements. On the other hand, the ISO 14001 standard is the most widely implemented by companies worldwide.

Therefore, this thesis seeks to explore and analyse specific research questions such as:

- Is there a relationship between companies that adopt more circularity practices and those with an implemented EMS?

- What is the relationship between the reporting and communication of environmental performance and the adoption of CE?

- Does the reporting of environmental performance allow measuring the implementation of environmental management within manufacturing firms?

- Is a particular mix of technological and management practices driving CE within manufacturing companies? What role does EMS play in such a configuration?

Thus, to answer these questions, this dissertation covers the theoretical foundation composed of Chapter 2 of Conceptual Framework, followed by the research development and results, with chapters 3 to 6, compounded by the publications of the empirical studies. Finally, chapter 7 is the discussion and conclusions.

1.3 Thesis methodology and structure

A mixed methodology is used for this research (see Figure 1) to answer the questions posed. The methodology is explained in detail in each of the empirical studies, such as sample sizes, statistical tests and software used.

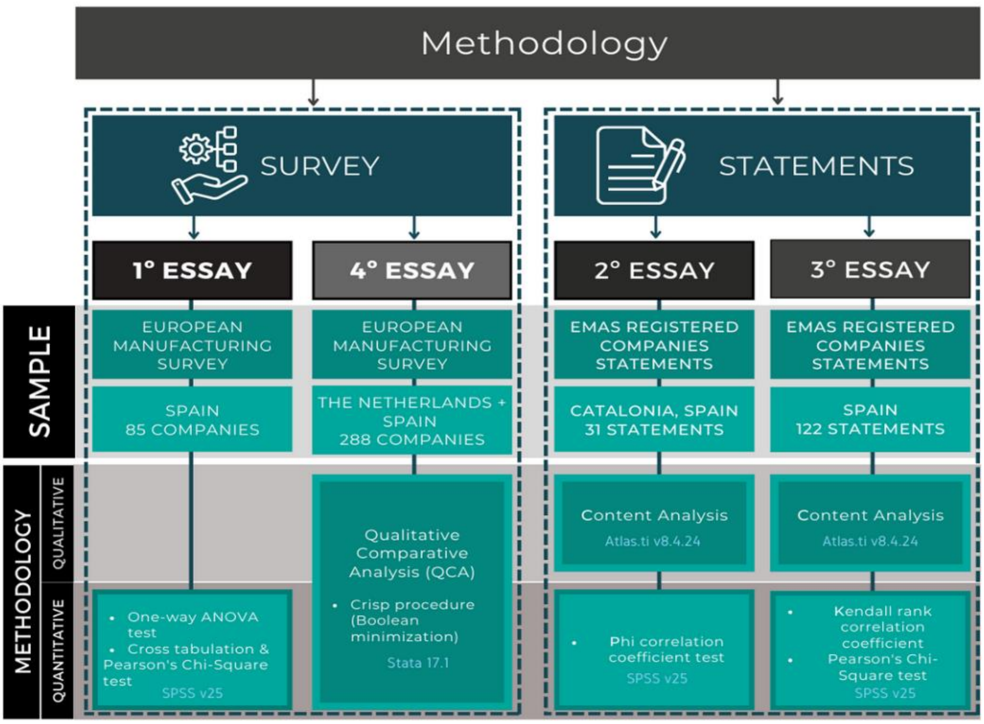

Figure 1. Methodology Structure. Own elaboration

The following sections present a review of the empirical studies that drove the research development and results from the chapters:

Chapter 3 [Essay 1]. Environmental policy and corporate sustainability: The mediating role of environmental management systems in circular economy adoption

Although some studies have mentioned that implementing an EMS promotes circularity adoption, we analysed 85 Spanish manufacturing companies in this chapter to corroborate it. The European Manufacturing Survey was used to establish whether there is a correlation between the companies that adopt more circularity practices and those that have an EMS.

Circularity practices and initiatives were established based on the model proposed by Prieto-Sandoval, Ormazabal, et al. (2018) This model classifies circularity at the micro level through five specific 'fields of action' that cover the product life cycle from beginning to end: *Take*, *Make*, *Distribute*, *Use* and *Recover*. One relevant aspect repeated in the literature is cooperation and connections between companies. Therefore, industrial symbiosis is treated independently in this study as a field, although it can intervene transversally in other fields of action.

Chapter 4. [Essay 2]. Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain

Chapter 4 discusses the EMAS and its public environmental statements in more detail. The study begins with a Content Analysis of 33 environmental reports from small and medium industrial and manufacturing companies in Catalonia, Spain. The objectives of this study are to find out what kind of information companies report, establish the European Commission's starting point in the reports and detect the CE practices mentioned by the companies.

The practices are determined through the prism of the fields of action. With the statistical method of Phi correlation, it sought to establish correlations (not causality) between the detected CE practices to discover drivers in circularity.

Chapter 5. [Essay 3]. EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy

This chapter is continued using the methodology of Content Analysis of environmental statements. However, the sample of analysis is extended from the whole of Spain, and large companies are considered too. Based on the neo-institutional theory, it was observed whether there was a mimetic influence between companies of different sizes with a more intensive reporting of circularity practices. The impact of the cohesive influence exerted by the European Commission on companies adapting EMAS was also analysed. The latter is mainly because the European Commission declares its commitment to CE, indicating that

EMAS is a promising tool towards circularity. Likewise, it indicates that the statements already have six key indicators that allow measuring circularity.

Thus, 122 environmental statements from EMAS-certified production centres in Spain were analysed, considering the use of indicators, figures and quantitative information in the reports. Finally, it was evaluated whether the information contained in the statements allows the implementation of some circularity indicator at the micro level that facilitates the measurement of the CE and provides institutional bodies with a tool to know the status of a sector or region.

Chapter 6. [Essay 4]. Practising more Circular Economy: enabling configurations of technological and managerial practices in the manufacturing industry

This last essay seeks not only to analyse the EMS as an organisational practice in itself but also to examine in the literature the management and technological practices that contribute to making companies more circular. Subsequently, under the lens of configurations, the practices are analysed to discover those sets that allow for greater circularity in the different stages of production. This study used data from the European Manufacturing Survey of 288 Dutch and Spanish companies using the QCA methodology.

1.4 Disertation outline

Table 1. Disertation outline

Chapter	Study	Objective	Theorical focus	Scope	Research design & Method
1	**Introduction**				
2	**Conceptual framework**				
3	**Essay 1.** Environmental policy and corporate sustainability: The mediating role of environmental management systems in circular economy adoption	Analyse the relationship between the implementation of EMSs and the adoption of CE initiatives in Spanish manufacturing firms	-Model of field of actions -Life cycle of products -Industrial simbiosis	-National: Spain -Sector: Manufacturing -Size: >20 employees	-Quantitative -Survey -Hypothesis test -The one-way ANOVA and Pearson's Chi-Square test
4	**Essay 2.** Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain	Analyse EMAS companies' environmental statements in order to identify and quantify the CE practices they have implemented	-Model of fields of actions -Environmetal Maturity Model	-Regional: Catalonia (Northeast Spain) -Sector: Industrial -Size: SMEs	-Mixed method: -Qualitative analysis : Content analysis -Quantitative: Phi coeficient
5	**Essay 3.** EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy	Analyse the information reported in the EMAS statements and determines whether it really is useful to be able to measure the level of adoption of the circular model in companies	-Neo-institutional theory: coercive isomorphism and mimetic isomorphism -10 R'imperatives /Loop Strategies	-National: Spain -Sector: Manufacturing -Size: SMEs and Large	-Mixed method: -Qualitative analysis: Content analysis -Hypotesis test. -Quantitative: Kendall rank correlation coefficien and Pearson's Chi-Square Test
6	**Essay 4.** Practising more Circular Economy: enabling configurations of technological and managerial practices in the manufacturing industry	Determine the configuration of practices or 'conventional actions' that organisations adopt and favour the transition towards a contribution to a more circular economy	-Managerial and technical CE practices -Organisational configurations	-International: The Netherlands and Spain -Sector: Manufacturing -Size: SME and Large	-Mixed method -Survey -Hypothesis test -QCA fuzzy-set with Quine-McCluskey algorithm
7	**Discussion and Conclusions**				

Chapter 2. Conceptual framework

"But the way to do it beter later is to do it as well as one can today,
There can't be anything but progress tomorrow"
Vincent Van Gogh

2.1 What is Circular Economy?

The concept of 'Circular Economy' emerged in the early 1990's, but it was in 2012 that it gained more notoriety through the publication of the Ellen Foundation. A review in Scopus shows the growing interest among academics. Searching for 'Circular economy' in 'Business, Management, Accounting' and 'Environmental Science' subareas from its inception to 2022 shows an exponential growth in publications in recent years (see Fig. 2), rising from 88 papers in 2015 to 3393 papers six years later.

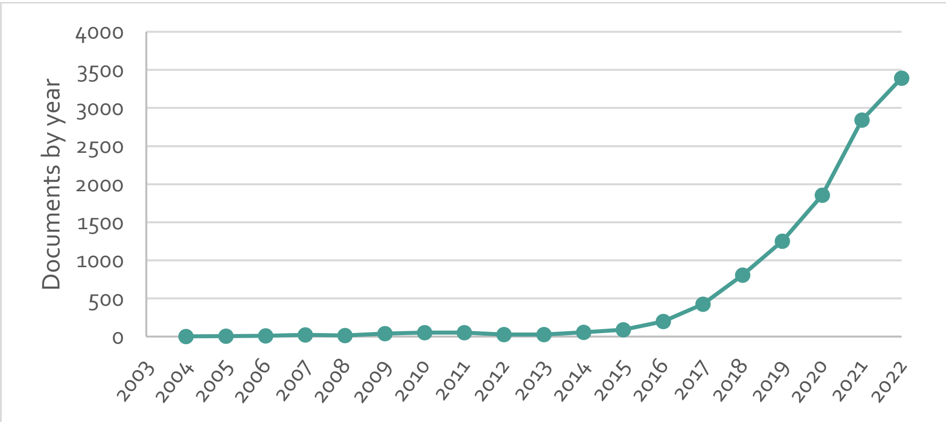

Figure 2. Evolution of literature including 'Circular Economy' in Scopus. Source: Scopus

Although there is widespread interest in the CE, at a conceptual level, academics have yet to reach a consensus on the definition of CE. The study by Kirchherr et al. (2017) examined the different existing definitions, finding a total of 114, pointing out that having such a variety of interpretations can represent a problem for the scholars in CE. The four most widely commented definitions in the literature are:

- *"an industrial system that is restorative or regenerative by intention and design. It replaces the ´end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impairs reuse, and aims for the elimination of waste through the superior design of materials, products, systems and within this, business models"* (Ellen Macarthur Foundation, 2015).

- *"a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling"* (Geissdoerfer et al., 2017).
- *"The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being"* (Murray et al., 2015).
- *"A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations"* (Kirchherr et al., 2017).

It is notorious that it has evolved over time and incorporated different aspects. For this thesis, we choose the definition proposed by Alfonso et al. (2020), which considering the previous definitions, defines it more holistically:

> "Circular economy is a system that is restorative and regenerative by intention and design, which supports ecosystem functioning and human well-being with the aim of accomplishing sustainable development. It replaces the end-of-life concept with closing, slowing and narrowing the resource flows in production, distribution and consumption processes, extracting economical value and usefulness of materials, equipment and goods for the longest possible time, in cycles energized by renewable sources. It is enabled by design, innovation, new business and organizational models and responsible production and consumption".

It should be noted that the concept of circularity has also moved into other areas, such as public policy. For example, in 2015, the European Commission published the first Circular Economy Plan (COM(2015) 614 Final, 2015) comprising 54 key actions, which was reinforced following the approval of the European Green Pact in 2019. The pact comprises a package of policy initiatives aiming to put the EU on the path to a green transition and achieve climate neutrality by 2050 (COM(2019) 640 Final, 2019). Similarly, the Circular Economy Agenda seeks to be a roadmap for incorporating a model for member countries. Other regions and countries, such as China, have a long tradition of CE, where they have incorporated comprehensive legislation and policies since 2000 (Bleischwitz et al., 2022; Yuan et al., 2020). At the institutional level, private bodies such as the Ellen MacArthur Foundation, WBCSD also support different organisations and companies to migrate their linear models to more circular and sustainable ones.

2.1.1 Main aspects of the CE

After understanding the concept, it is essential to know the rules or fundamentals that define the model and bring the conceptual and practical aspects closer together. In this sense, we have the principles and strategies. The Ellen MacArthur Foundation developed the butterfly model of circularity that seeks to explain how materials, components and products can circulate in both technical and biological cycles, retaining their value as much as possible and making efficient use of the new resources enter the system. Thus, they mention three general principles:

Principle 1: Preserve and enhance natural capital by controlling finite stock and balancing renewable resources flows.

Principle 2: Optimise resources yield by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles.

Principle 3: Foster system effectiveness by revealing and designing out negative externalities.

Figure 3 shows the CE butterfly model and its relationship to the principles of circularity.

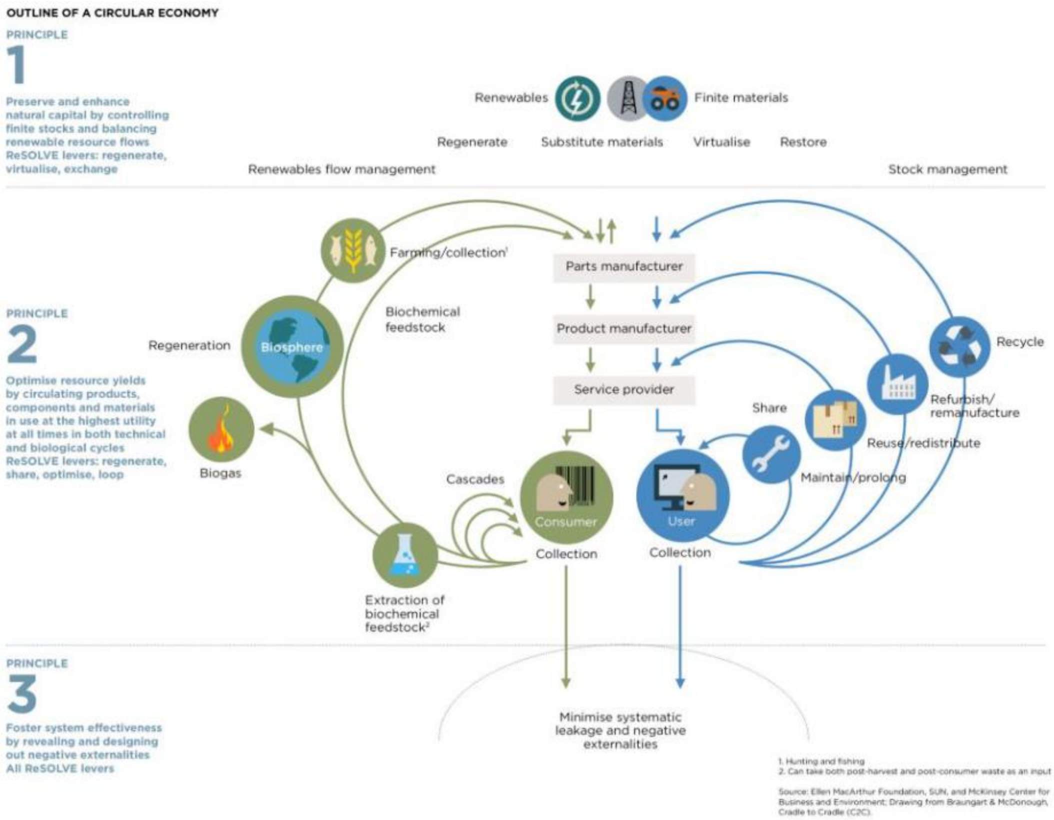

Figure 3. CE Butterfly model and principles. Source: EllenMacArthur Fundation

Circularity principles have also been discussed in the literature, often confusing or overlapping with strategies (Cui, 2021; Geissdoerfer et al., 2017; Stumpf et al., 2021). Having framed the principles, we turn to loops, all those biological and technical cycles that promote value retention and lead to lower resource and energy use. Loops have been classified between short, medium and long depending on the distance between the user/consumer and the circularity actions performed to retain value. Reike et al. (2018) mention the evolution of the actions or strategies involved in loops, starting from the well-known 3Rs, until reaching the 10Rs, also called circularity imperatives. Table 2 shows each of them and their relationship with the classification of loops.

Table 2. Value retention options – R'Imperatives

	Value Retention options R0-R9	**Consumers/Users**	**Producers (Production and Design)**
Short Loops: R0 – R3	**Refuse R0**	The choice to buy less, or use less, which may apply to any consumption article aiming at prevention of waste creation	refuse the use of specific hazardous materials or any virgin material; design production processes to avoid waste
	Reduce R1	Using purchased products less frequently; use them with more care and longer. Also, participation in the 'sharing economy'	Stressing using less material per unit of production or referring to 'dematerialization' as explicit steps in product design.
	Resell/Reuse R2	Direct re-use of a product, without any change in its status, after minor adaptations or fine tuning. This implies buying second hand or finding a buyer for a product that was not or hardly in use, possibly after some cleaning or minor adaptations for quality restoration by the consumer.	"Direct re-use" as economic activity via collectors and retailers, possibly with quality inspections, cleaning and small repairs; (commercial and non-commercial); "Direct re-use" of unsold returns or products with damaged packaging; multiple re-uses of (transport) packaging. "re-use in fabrication" apply recycled materials
	Repair R3	Repairing can be done by different actors and with or without change of ownership. Repair operations can be performed by the customer or people in their vicinity, at the customer's location, and through a repair company.	Businesses may send recollected products to their own repair centers, to manufacturer-controlled, or to third party repair centers). Finally, we can distinguish 'planned repair' as part of a longer lasting maintenance plan or 'ad-hoc'repairs
Medium Long Loops: R4 - R6	**Refurbish R4**	Buying of reconditioned products. Subscription to rental or leasing services for products with these characteristics.	The overall structure of a large multi-component product remains intact, while many components are replaced or repaired, re-sulting in an overall 'upgrade' of the product
	Remanufacture R5	Buying of remanufactured products. Subscription to rental or leasing services for products with these characteristics.	full structure of a multi-component product is disassembled, checked, cleaned and when necessary, replaced or repaired in an industrial process, recycled parts may be used expected retained quality more tempered: "up to original state, like new"
	Repurpose R6	Re-use an already discarded product with a new function. function.	reusing discarded goods or components adapted for another function, the material gets a distinct new lifecycle. This seems to denote both low and

			high value end-products. It is popular in industrial design and artists communities e.g.: 'rethink', 'fashion upgrading' or 'part reuse'.
Long Loops: R7 - R9	**Recycle Materials R7**	To give back as separate waste streams	processing of mixed streams of post-consumer products or post-producer waste streams using expensive technological equipment, including shredding, melting and other processes to capture (nearly) pure materials. Wherefore recycled materials are also called 'secondary' materials. Too, apply recycled materials.
	Recover (energy) R8	Transition to self-sustainable housing (solar panels, water recirculation systems), electric cars and use of energy efficient appliances and equipment.	capturing energy embodied in waste, linking it to incineration in combination with producing energy, distilled water or use of biomass. Services of reverse logistics.
	Re-mine R9	n.a.	retrieval of materials after the landfilling phase "cannibalization"; hi-tech landfill mining or urban mining. Apply recycled materials

Based on Reike et al., 2018; Vermeulen et al. (2019)

2.2 Environmental Management Systems

Although the concept of 'Environmental Management dates back to the late 1990s and is first mentioned in Gorden & Gorden's book (1972) 'Environmental Management Science and Politics', it was not until the 1990s that the so-called 'Environmental Management System' emerged.

The US Environmental Protection Agency (US EPA, 2022) defines it as "a framework that helps an organisation achieve its environmental goals through consistent review, evaluation, and improvement of its environmental performance. The assumption is that this consistent review and evaluation will identify opportunities for improving and implementing the organisation's environmental performance. The EMS itself does not dictate a level of environmental performance that must be achieved; each organisation's EMS is tailored to its own individual objectives and targets".

The main objectives of an EMS, according to Sunderland, (1997) and Watson (1996) are:

- ✓ Identify and control environmental aspects, impacts and risks relevant to the organisation.
- ✓ Improve its environmental policy and facilitate the achievement of its objectives while complying with environmental legislation.
- ✓ Define the basic principles that guide the organisation towards its environmental responsibilities in the future.
- ✓ Establish short, medium and long-term objectives for the company's environmental performance, analysing the cost-benefit balance for the organisation and its stakeholders (including shareholders).

- ✓ Determine which resources are necessary to achieve the pre-established objectives, assigning responsibilities in each case.
- ✓ Define and document the different tasks and operations, responsibilities, authority and procedures to ensure that all workers act on a daily basis to minimize or eliminate the negative impacts that the company could cause on the environment.
- ✓ Improve the organisation's communication and train people to assume their responsibilities.
- ✓ Measure environmental performance daily, making it possible to see if the predetermined objectives are being achieved and modify what is necessary.

It should be noted that EMS are framed in the "Shewhart cycle" methodology proposed by W. Edwards Deming. Based on the Plan-Do-Check-Act (PDCA), which must be implemented repeatedly in spirals of increasing knowledge of the system that converge in the final objective. Although EMS can vary according to the type of organisation, size, activities performed, products and services offered, the basic elements (Giménez Leal & Valls Pasola, 2001) that make it up are:

- **Environmental policy:** It frames the management's commitment to correct environmental management. It should contain the main objectives that the company wishes to achieve, as well as the company's intentions in terms of environmental performance.
- **Environmental program or action plan:** The organisation translates the objectives into specific and, as far as possible quantifiable activities for subsequent evaluation and adjustment of actions. It also defines the human and financial resources needed to meet the proposed objectives in the stipulated period.
- **Organisational structure:** Responsibilities are assigned, and tasks are delegated within the organisation. In the case of several sites or centres, responsibilities are established at a general level and for each centre or activity.
- **Integration of environmental management in the company's operations:** A plan of environmental procedures describing the measures and actions required to implement the environmental program in the company's operations.
- **Control, measurement and recording:** Documentation and control of the results of specific actions, as well as the effects of environmental improvement.
- **Corrective and preventive actions:** Adjustments are established to eliminate existing or potential non-conformities.
- **Environmental audits:** internal checks are performed on the adequacy and effectiveness of EMS implementation. In some cases, they also perform the task of data verification and reporting.
- **Training and information:** The environmental policy and the environmental program of the organisation or facility are disseminated to ensure that the entire organisational structure is aware of the EMS and its environmental tasks and responsibilities regarding its workplace activities.

- **Review of the EMS:** Periodic evaluation carried out by the Management to know the effectiveness and implementation of the system.
- **External communication and community relations:** Finally, the organisation seeks to communicate its objectives, actions, environmental performance and results obtained in the improvement plan to society and interested parties.

Fig. 4 shows the guide for implementing an EMS proposed by Barwise (1998), which includes the different stages, steps and activities related to adopting an EMS.

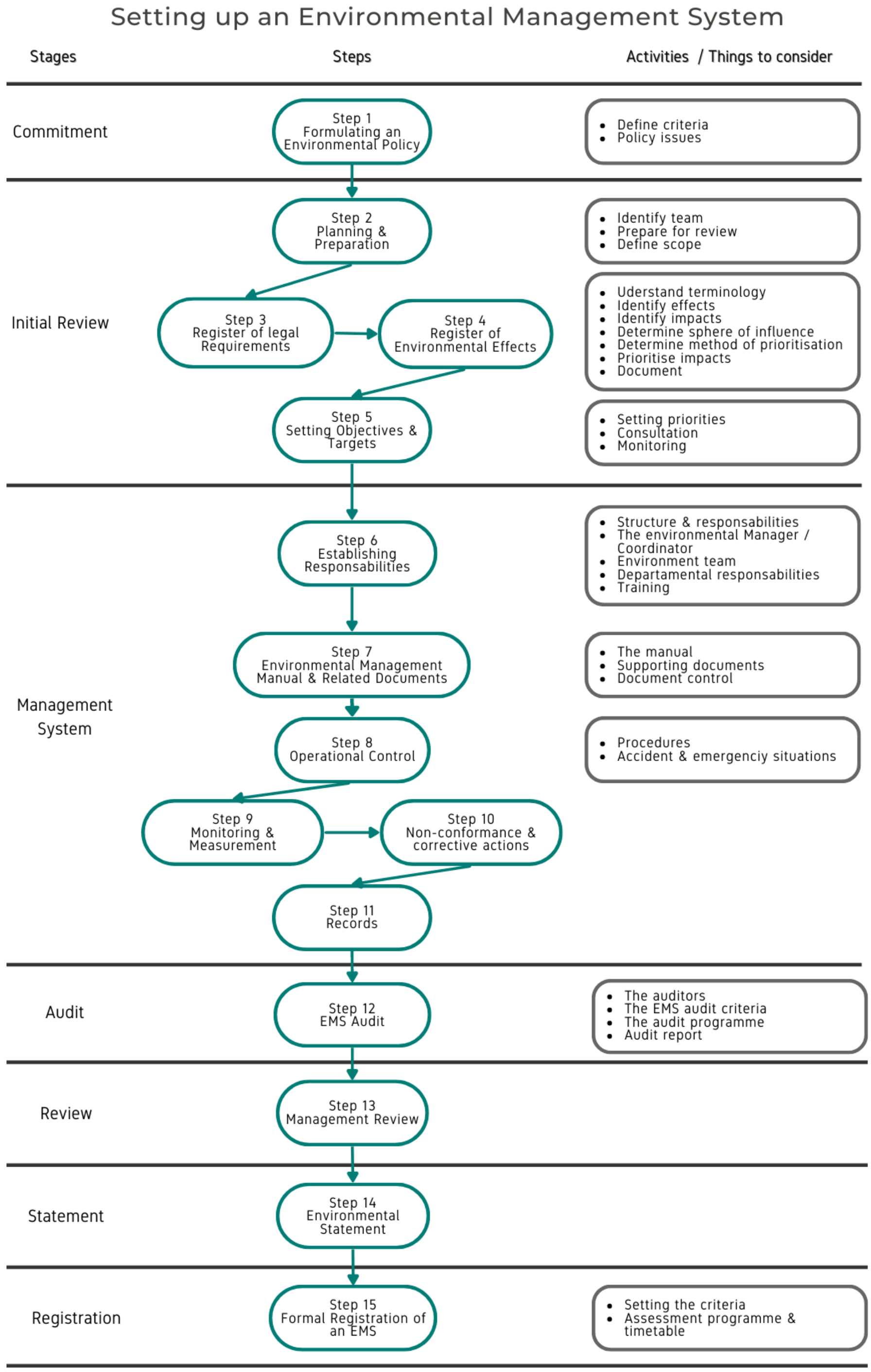

Figure 4. Setting up an Environmental Management System by Barwise, 1998

2.2.1 The ISO14001:2015 Standard

Standard published since September 1996 by the International Organization for Standardization (ISO) specifies the requirements for registration, self-assessment and certification of an EMS in a company. The organisation's environmental policy must contain three fundamental commitments: Compliance with environmental legislation and regulations affecting the company's activities, continual improvement in all environmental performance and pollution prevention. The standard is based on the PDCA methodology (see Figure 5) but does not establish specific EMS requirements, which is one of the limitations of this EMS. Thus, a company with ambitious goals and objectives in its environmental plan and another with more modest objectives can be equally certified. Finally, ISO 14001 certification can be granted by governmental or private certifying agencies under their own responsibility.

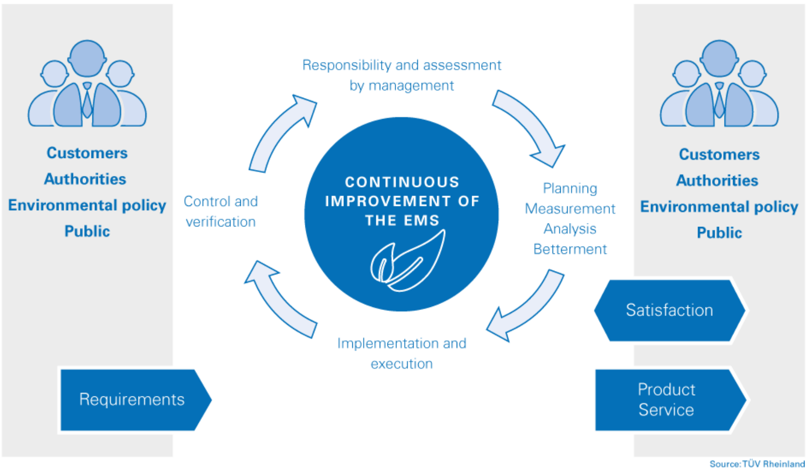

Figure 5. ISO14001 certification process. Source: TÜV Rheinland

2.2.2 The Eco-Management and Audit Scheme regulation

EMAS is an instrument created by the European Commission and issued as Regulation (EC) No 1221/2009 of the European Parliament and of the Council on 25 November 2009 (Regulation (EC) No 1221/2009, 2009), as amended by European Commission Regulation (EU) 2017/1505 of 28 August 2017 (Regulation (EU) 2017/1505, 2017). EMAS is both an alternative management system to ISO 14001, as well as an extension of the international standard (Ociepa-Kubicka et al., 2021), (See Figure 6). Although it fulfils the primary purpose of an EMS by promoting the establishment and implementation of environmental policies, programs and management systems, it also has some differentiating features. For example, the objective and periodic systematic evaluation of the proposed objectives and goals, the verification of the information by a third party and the publication of its annual environmental management and performance reports, known as Statements. Table 3 shows the main characteristics and differences between the two EMSs mentioned above.

Figure 6. EMAS certification process. Source: EMAS WebPage

Table 3. Characteristics and differences between EMAS and ISO14001

Elements	EMAS	ISO 14001:2015
Type of issued organization:	Governmental	Non-governmental
Name of issued organization:	European Parliament and Council	International Organization for Standardization
Objective:	Environmental performance improvement	Environmental performance enhancement through EMS improvement
Range:	European	International
Nature:	Public regulation	Private standard
Main drivers to adopt EMS:	Internal motivation	Pressure of external stakeholders
Dialogue with external parties (and external reporting):	Mandatory	Voluntary
Official registration by authorities:	Publicly accessible register record (organization receives the registration number)	No official register
Audits:	Inspection of documents and visits in institutions carried out according to regulation. Evaluation of environmental performance improvement. Data from environmental statement needs validation.	No certification rules in standard (different standards for auditing and certification). Evaluation of EMS performance without specified frequency.
Environmental aspects:	Comprehensive initial environmental review of the current status of activities, products and services.	Requires only a procedure to identify environmental aspects. Initial review is recommended, but not required.

Source: Ociepa-Kubicka et al. (2021)

2.3 Literature Review

After observing the different concepts framing this thesis, we move on to the literature review (LR). As mentioned Gall et al. (1996), the literature review allows researchers to: a) delimit the research problem and avoid fruitless approaches, b) search for new lines of research and identify recommendations for research, and c) obtain methodological knowledge, as well as seek support for grounded theory. Other relevant characteristics of LR are rationalising the problem, identifying significant variables related to the topic, and establishing the context, distinguishing what has been done from what needs to be done (Hart, 1998).

Examining the adoption of circularity principles and their relationship with EMS in the manufacturing industry, knowledge in this area is fragmented, so a literature review that analyses the findings of other research is desirable. Thus, this LR aims to investigate state of the art in the relationship between EMS and CE and to compare which characteristics and practices of EMS facilitate the adoption of CE strategies within companies. This knowledge will establish the key aspects to be considered in designing the empirical studies that make up this thesis.

The LR comprises the following structure:

1. Description of the methodology
2. General characteristics of the included studies, publication trends, regions and journals.
3. Synthesis and comparison of the evidence found.
4. Discussion and conclusions

2.3.1 Methodology

This LR used the systematic literature review methodology, summarizing the results of subsequent literature and explaining the differences in the studies. This methodology allows quality control by employing academic databases. (SCOPUS & Web of Science).

a. *Keywords*

The keywords established were 'circular economy', 'environmental management system', and related words such as 'EMAS', 'ISO14001' 'practices', 'transition', 'principles', 'adoption' e 'implementation'.

The search was segmented to journal types in the field of 'Business, Management and accounting' and to 'Environmental Science'. The search language was also restricted to English. This LR started in October 2019 and ended in August 2022, although no specific time range was established.

This way, the following results were obtained by word combination in the two databases (table 4):

Table 4. The number of articles from each combination of keywords search

	Keywords	SCOPUS	WoS	Filter
SLR 1	"circular economy" AND "environmental management system"	29	15	31
SLR 2	"circular economy" AND "environmental management system" AND practic*	8	5	10
SLR 3	"circular economy" AND "environmental management system" AND adopt*	12	6	13
SLR 4	"circular economy" AND "environmental management system" AND implement*	11	9	15
SLR 5	"circular economy" AND "environmental management system" AND tool	7	2	7
SLR 6	"circular economy" AND "environmental management system" AND indicat*	8	5	10
SLR 7	"circular economy" AND "environmental management system" AND report*	2	1	3
SLR 8	"circular economy" AND "environmental management system" AND transition*	8	7	11
SLR 9	"circular economy" AND "environmental management system" AND principl*	8	3	8
SLR 10	"circular economy" AND "environmental management system" AND industr*	9	3	12
SLR 11	"circular economy" AND "environmental management system" AND manufactur*	5	4	7
SLR 12	"circular economy" AND "environmental management system" AND "ISO14001"	1	1	1
SLR 13	"circular economy" AND "environmental management system" AND "EMAS"	6	5	7
SLR 14	"circular economy" AND "environmental management" AND report*	22	36	51
	Total	**136**	**102**	**186**

b. Exclusion criteria

Articles that were not peer-reviewed (4), those focused on other sectors such as Education or Health (7), and finally, those that did not relate EMS to the adoption of CE (65) were excluded.

c. Inclusion criteria

It started with a manual selection process. During the process, we chose articles that test or explain the effect of EMS on adopting circularity in the manufacturing industry. Finally, 18 articles met these criteria and were included in the review (see figure 7 for the decision tree).

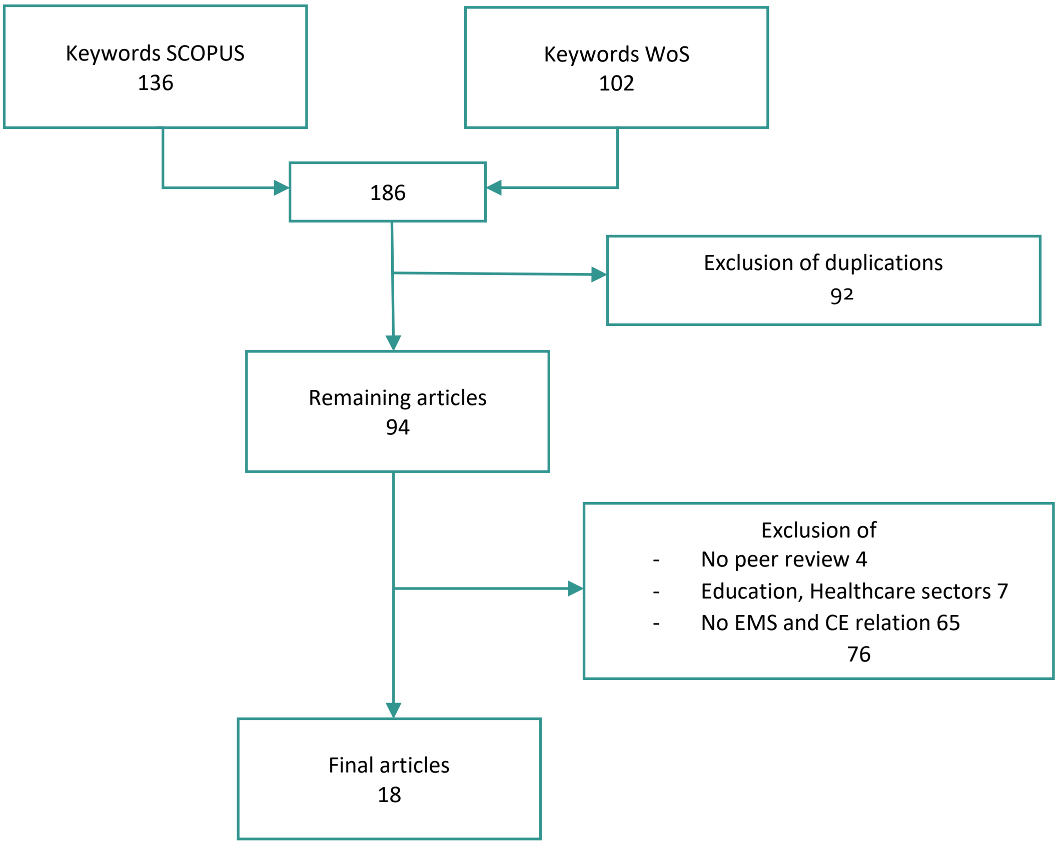

Figure 7. Decision tree of data selection

2.3.2 General characteristics of the included studies

From the included studies, we can see in Table 5 some of their characteristics, such as the distribution of publications per year, per region and per journal. The country with the highest number of publications is Italy, with six articles, followed by China, India and Spain, each with two publications respectively. Denmark, Greece, Pakistan, Portugal, Poland and Sri Lanka with one publication each.

Table 5. Number of publications by country

Countries	No. of Publications	Porcentage
Italy	6	33%
China	2	11%
India	2	11%
Spain	2	11%
Denmark	1	6%
Greece	1	6%
Pakistan	1	6%
Portugal	1	6%
Poland	1	6%
Sry Lanka	1	6%
Total	18	100%

Although no specific time range was established for the LR, the articles to be reviewed span from 2018 to 2022, with the year 2022 having the highest number of publications related to CE and EMS (6).

Table 6. Number of publications per year

Year	No. of Publications	Porcentage
2018	3	17%
2019	2	11%
2020	6	33%
2021	4	22%
2022	3	17%
Total	18	100%

Publications are distributed among nine journals (see Table 7): Journal of Cleaner Production and Business Strategy & the Environmental are the ones where most related studies are published, 5 and 4 publications, respectively. They are followed by Environmental Science and Pollution Research and Sustainability, with two publications each. The others have one publication each: International Journal of Production Research, Journal of Knowledge Management, Science of The Total Environment, Sustainable Production and Consumption, Sustainability Accounting, Management And Policy Journal.

Table 7. Distribution of publications by journal

Journal	No. of Publications	Porcentage
Journal of Cleaner Production	5	28%
Business Strategy and the Environment	4	22%
Environmental Science and Pollution Research	2	11%
Sustainability	2	11%
International Journal of Production Research	1	6%
Journal of Knowledge Management	1	6%
Science of the Total Environment	1	6%
Sustainable Production and Consumption	1	6%
Sustainability Accounting, Management and Policy Journal	1	6%
Total	18	100%

2.3.3 Synthesis and comparison of evidence found

Within the LR, we can find studies that corroborate the EMS as facilitating tools in the transition. However, the discussion focuses on how the incorporation of an EMS, based on reasons of efficiency or legitimacy (Leseure et al., 2004; Voss, 2005), brings it closer or further away from being considered an effective tool in the transition towards circularity. In the following, we will comment on the main findings found in the different studies.

2.3.3.1 Relationship of EMS with the CE

In the literature reviewed, 15 studies point to the positive relationship of EMS with the adoption of circularity principles. Marrucci et al., in their 2019 literature review (Marrucci et al., 2019) analyse different Sustainable Consumption and Production (SCP) tools, among which they highlight as the first important area of development of the EMS in the production phase and their level of integration with the CE. Later in their 2022 study, Marrucci et al. (2022) pointed out that a correct internationalisation of EMS, together with dynamic capabilities, facilitates the implementation of CE. The study by Jain et al. (2020) revealed that organisations that leverage EMS to achieve CE performance are more effective in coping with coercive pressures by leveraging EMS. Also, Kristensen et al. (2021) indicated that the inclusion of CE in EMS has the potential to provide new value from EMS and provide companies with a platform for continuous improvement and systematic work with CE.

We also found some studies that reviewed different types of EMS separately. Merli & Preziosi, (2018) highlighted the positive outcomes of EMAS, such as maximising material productivity and energy efficiency, creating value from waste and implementing of standardised environmental indicators and how these can help organisations in the transition towards the CE. On the other hand, Yang et al. (2019) proposed subsystem interaction and complementarity of CE practices. It Highlights EMSs and suggests that a manufacturing company will be better off adopting an EMS such as ISO 14000 because it will be able to integrate environmental practices deep into its operational frameworks. Also, Fonseca et al. (2018) noted that EMS certification and strategic choices to improve environmental performance and achieve a sustainable business model are related to higher levels of CE intensity.

In other empirical studies, we find Sharma et al. (2020) in which they mention that the critical enabler for the e-WM problem is the correct implementation of a comprehensive and systemic environmental programme within the organisation, such as an EMS. Khan & Ali (2022) observed 16 critical enablers in the transition to the circular model in Pakistan, finding EMS as the second most relevant enabler after the design of more effective regulations for waste management.

2.3.3.2 Organisational enablers

Although studies have looked at the relationship between EMS and CE from different perspectives, alluding to economic, technological and political or governmental factors, it is mainly in the organisational sphere where the authors have delved more deeply. Therefore, under the framework of organisational enablers, understood as the skills, knowledge, tools, resources and culture of the organisation that will enable it to achieve the strategy (Ball & Lunt, 2019). we classify the following enablers detected in the literature observed:

a) *Dynamic capabilities:* these are essential in the integration of EMS requirements, and the internalisation of EMS positively influences not only environmental and economic performance but also CE performance and environmental reputation (Marrucci et al., 2022).
b) *Absorptive capacity building (ACAP):* Understanding ACAP as "the ability of a firm to recognise the value of new and external information, assimilate it and apply it for business purposes" showed that ACAP would significantly facilitate the internalisation of CE and EMS (Marrucci et al., 2021a).
c) *Hard and soft elements -Socio-Technical Systems (STS):* Integrating CE into EMS requires both hard and soft elements. Hard elements for EMS include the extension of existing tools, eco-design, and systems to ensure quality, availability and markets of secondary raw materials, but also soft tools and capacities such as standardised indicators for micro-level CE, identification of correct CE targets in EMS, documenting CE efforts to stakeholder (Kristensen et al., 2021).
d) *Green Human Resources Management (GHRM):* It measures the influence of human capital on CE. Integrating GHRM practices into the practical experience of organisations can stimulate the green behaviour of the organisation's employees, not only in the context of the workplace but also in their daily life activities (Marrucci et al., 2021b).
e) *Institutional Pressures and Organisational Flexibility:* Coercive pressures (CP) and mimetic pressures (MP) mediate through EMS to achieve CE performance. Flexible organisations, compared to rigid ones, are more effective in coping with coercive pressures by harnessing EMS (Jain et al., 2020).

2.3.3.3 Aspects requiring further attention from EMS for the transition to the CE

The authors also suggest a greater focus on the following aspects to harness and enhance EMS as an effective tool in the transition to circularity:

- **Circularity objectives:** It requires defining CE objectives and allocating economic and human resources, encouraging stakeholder participation (Marrucci et al., 2021a). They also suggest that companies should first set qualitative or soft targets to experiment with CE strategies and identify relevant initiatives and focus areas, followed by a possible exploration of quantitative or challenging targets for CE strategies in the context of each company (Kristensen et al., 2021).

- ***Indicators*:** Within soft skills and capacities, Kristensen et al. (2021) mention the need to establish standardised indicators for micro-level CE. In the case of EMAS, indicators would allow monitoring of companies by organisations at the meso-level by establishing a set of mandatory and comparable performance indicators that require organisations to meet pre-established environmental targets or performance indicators that are more aligned with circularity (Marrucci & Daddi, 2021). Additionally, Merli & Preziosi (2018) also point out, concerning EMAS, that environmental performance indicators implemented by registered organisations are the basis of transparency of this EMS and can stimulate follow-up progress towards a CE, and therefore suggest further exploiting such a system.

- ***Environmental information and reporting:*** Although EMSs have always been considered a strategy to overcome information asymmetry between companies and stakeholders (Marrucci & Daddi, 2021), information reporting presents many things that could be improved. The authors point out in their study that around 40% of EMAS-registered organisations did not disclose according to EMAS requirements on KPIs, thus calling into question environmental reporting and environmental disclosure commitments. However, the authors highlight the importance of documenting CE efforts to stakeholders (Kristensen et al., 2021), as well as the use of Environmental Management Accounting (EMA) tools can be associated with CE management in companies and the quality of disclosure (Scarpellini, Marín-Vinuesa, et al., 2020). Some scholars indicate the need for global environmental reporting to consider comparability, verifiability and comprehensibility as characteristics that determine the quality of reporting (Haller et al., 2018). They also emphasise the need for environmental reporting to be institutionalised through professionalisation and other means of global sustainability reporting templates (Dagiliene et al., 2020; de Villiers & Alexander, 2014).

- ***Verification and certification:*** Following on from the above, opinions on the sense of transparency of verification are pretty divided. The study by Marrucci & Daddi (2021) points out that being verified by third parties may not guarantee the ability of EMAS-registered organisations to contribute to their environmental performance, in many cases because of the existing conflict of interest on the part of the verifying organisations. On the other hand, some organisations may use EMS only to obtain certification to enhance their environmental reputation rather than to develop greening practices and environmental performance improvements. On the other hand, Dagiliene et al. (2020) in their study confirmed that companies that provide voluntary external verification do report more significant environmental text information and higher environmental KPIs from an CE perspective than companies that do not provide such verification.

- ***Regulation and policy:*** CE activities are still relatively modest, a more favourable context (fiscal, legal, organisational, and so on) is required, and additional governmental actions to promote CE would be most welcome (Fonseca et al., 2018). (Marrucci et al., 2022) point out that policymakers still need to support the transition with adequate measures and that, for example, in the case of EMAS, they should consider revising the requirements (Marrucci & Daddi, 2021). They also point out that EMS can be effective if it focuses on manufacturing green products, developing stringent legislation and supporting producers to implement environmental management practices (Sharma et al., 2020). Some solutions they propose to boost the adoption of EMS as a tool to control and monitor environmental problems in industrial areas are regulatory relief measures that should be included in various legislations and promoted through publicity activities involving stakeholders (Zorpas, 2020). Additionally, it is recommended that policymakers create awareness, develop infrastructure, enact and enforce laws and support collaborations and help practitioners improve corporate communication practices while developing business operations towards a CE (Gunarathne et al., 2021).

- ***Green clusters:*** Sharing information and knowledge, focusing on collective goals and developing cross-organisational partnership management capabilities improve sustainability, so voluntary environmental practices such as EMSs can foster sustainability among companies through the development of green clusters (DeBoer et al., 2017; Marrucci et al., 2022; Niesten & Jolink, 2015). For an EMS such as EMAS, they suggest identifying strategies to locate potential energy and material loops within and between organisations and using environmental statements to communicate by-product availability to stakeholders (Marrucci et al., 2019).

2.4 Relationship between State of the art and the contributions

Based on the aspects that require further attention in the field, the following four chapters seek to contribute to this area of knowledge by incorporating some of the enablers mentioned and considering the EMS requirements for the transition to CE (See table 8).

Table 8. Development of research according to literature review

Chapter	Research Question	Organisational Enables	Issues for further attention in CE+SME observed in the studies
Chapter 3: Environmental policy and corporate Sustainability: The mediating role of environmental management Systems in circular economy adoption	Is there a **relationship** between companies that adopt more circularity practices and those with an implemented Environmental Management System?	-Dynamic capabilities	-Green Clusters
Chapter 4: Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain	What is the relationship between the **reporting and communication** of environmental performance and the adoption of CE?	-Dynamic capabilities	-Environmental information and reporting -Regulation and policy -Verification and certification
Chapter 5: EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy	Does the reporting of environmental performance allow **measuring** the implementation of environmental management within manufacturing firms?	-Dynamic capabilities -Institutional Pressures and Organisational Flexibility	-Environmental information and reporting -Regulation and policy -Verification and certification -Indicators
Chapter 6: Practising more circular economy: enabling configurations of technological and managerial practices in the manufacturing	Is a **particular combination of technological and management practices** driving CE within manufacturing companies? What role does EMS play in such a configuration?	-Hard and soft elements -Socio-Technical Systems (STS)	

Chapter 3. Environmental policy and corporate Sustainability: The mediating role of environmental management systems in circular economy adoption

This chapter is based on: Barón Dorado, A., Giménez Leal, G., de Castro Vila, R. (2022). "Environmental policy and corporate sustainability: The mediating role of environmental management systems in circular economy adoption" Journal Corporate Social Responsability and Environmental Mangement, 1–13. https://doi.org/10.1002/csr.2238

ENVIRONMENTAL POLICY AND CORPORATE SUSTAINABILITY: THE MEDIATING ROLE OF ENVIRONMENTAL MANAGEMENT SYSTEMS IN CIRCULAR ECONOMY ADOPTION

CORPORATE SOCIAL RESPONSABILITY AND ENVIRONMENTAL MANAGEMENT

Alexandra Barón Dorado, Gerusa Giménez Leal, Rodolfo de Castro Vila

ABSTRACT

Companies see adopting the Circular Economy (CE) model as an opportunity to become more sustainable and aligned to the growing demand for more environmentally friendly products. Governments, institutions and researchers alike have highlighted the importance of organisations having an environmental policy, and that this policy be implemented through effective Environmental Management Systems (EMS) as the way to achieving corporate sustainability. However, despite exploring the relationship between EMSs and moving towards the circular model in the business world, research on this increasingly critical issue remains limited. To address this gap, research was carried out on 85 Spanish manufacturing companies. Results show that implementing an EMS has a positive effect as the companies analysed adopted a higher number of CE practices. From a managerial perspective, managers are challenged to show leadership initiative by exploring new, more sustainable ways of operating that engage new stakeholders. Implications for regulators focus on enhancing the circularity of EMS.

Keywords: Circular Economy, Environmental Management Systems, Environmental Policy, Manufacturing Industry, Sustainability, Survey

3.1 Introduction

According to the Circularity GAP Report 2020, only 8.6% of the global economy is currently circular, compared to 9.1% two years ago. This negative evolution in the global circularity gap is explained by high extraction rates, continuous stockpiling and low levels of end-of-use processing and recycling. In this context of overexploited resources under pressure, the importance of taking sustainability into consideration in business strategies, business models and product and service design is no longer being questioned (Lewandowski, 2016; Manninen et al., 2018; Witjes & Lozano, 2016). The latest Eurobarometer survey, in July 2020, asked about the objectives of the European Green Pact (European Commission, 2019), and revealed that Europeans continue to consider CE as a top priority. Moving towards a more competitive and responsible CE is key for progress and social welfare. Thus, the European Union (EU) has made CE a strategic policy to promote this new model of production and consumption at all levels. Spain is no newcomer to this situation and already has initiatives at state, regional and local level from which to build a coherent and systematic CE model. Within this context, the Spanish Circular Economy Strategy (EEEC)(Ministerio de Economía Industria y Competitividad, 2018) faces the challenge of implementing circularity in the Spanish economy.

Traditionally, governments and organizations have focused more intensively on the end-of-production-cycle phase (Ministerio de Agricultura, 2015), but CE aims to concentrate efforts on the design phase and to achieve product durability by combating programmed obsolescence and promoting servitisation, reuse, refurbishment, recycling and reprocessing of components. This transition towards CE should be done in a way that enables companies to be efficient without incurring excessive burdens or hindering the company's growth, given that larger size improves productivity, contracting capacity, investment and internationalisation. This is of the utmost importance for Spanish manufacturing firms, which compared to other leading EU countries, are characterised as small companies and micro-enterprises. The small size of Spanish manufacturing companies often implies lower investment capacity, especially in product design and R&D&I, and greater difficulty developing projects which can improve the use of production resources, as well as internationalisation projects (Ministerio de Economía Industria y Competitividad, 2018).

Governments, institutions and researchers alike have highlighted the importance of EMSs and eco-labels as tools or instruments to enable circular transformation and the development of effective eco-innovations in companies (BSI Standards Publication, 2017; European Comission, 2017; Evans et al., 2015). EMSs enable companies to assess, manage and improve their environmental impacts, thus ensuring excellent environmental performance. Thus, the EEEC has established Strategic Orientation #5 in the area of Production Efficiency (SO5) to introduce guidelines to increase innovation and the overall efficiency of production processes. This is done through digital infrastructures and services and by adopting measures such as EMS implementation, thus boosting competitiveness and sustainable business growth. This strategy, therefore, highlights that EMS, through the necessary analysis of the life cycle of products/services, implicitly contribute to the CE model approach, and can help companies make the complex transition to CE. Moreover, proper CE implementation can boost innovation, financial performance and competitiveness of companies by increasing their resource efficiency (European Comission, 2017).

In the world ranking of EMS certifications, data from the ISO Survey 2019 place Spanish companies in fourth place after China, Japan and Italy in relation to the international standard ISO 14001, with 12,871 certified companies. Regarding the EMS promoted by the European Commission (EC), the European Eco-Management and Audit Scheme (EMAS), Spain is in third position after Germany and Italy, with 968 companies in January 2021 (EMAS Register). Despite these outstanding EU and global positions regarding EMS adoption, the latest Sustainable Development Report 2019 (benchmark) places Spain in 21st position out of 162 countries with respect to Sustainable Development Goals (SDGs). Countries leading the ranking are Sweden, Denmark and Finland, although the report points out that no country in the world has yet achieved the 17 SDGs, nor is on track to achieve them by 2030. This report also mentions that progress towards responsible production and consumption (SDG 12) is a significant challenge for Spain, highlighting the challenging path we have ahead of us.

Although much research has been conducted on the benefits and effects of environmental certifications in organisations (Álvarez-García et al., 2018; Bravi et al., 2020; Giménez et al., 2003; Murmura et al., 2018), the authors have found no studies exploring whether a direct relationship between these certifications and CE adoption in companies exists. Thus, exploring the relationship between EMSs and the business world's move towards the circular model is an increasingly crucial issue.

The main objective of this paper is to analyse the relationship between the implementation of EMSs and the adoption of CE initiatives in Spanish manufacturing firms. The rest of the paper is structured as follows. In section 2, the theoretical framework of the study is presented, including a discussion of the concept of CE and its practices applied to the manufacturing firm and a description of EMSs; the formulation of the hypotheses of the study is also presented in this section. Section 3 describes the methodology of the empirical study. The results of the empirical study are presented in section 4. The paper concludes with a summary of the main conclusions and implications.

3.2 Theoretical framework

3.2.1 Definition of circular economy

Nowadays the concept of CE is commonly found in the political and scientific sphere, as well as in business and society in general. There is no consensus on its definition as it varies according to the issues it seeks to address, or the field of knowledge from which it is approached (Aranda-Usón et al., 2020; Geissdoerfer et al., 2017; Katz-Gerro & López Sintas, 2018; Pieroni et al., 2019). What is agreed on, however, is that CE is an economic model aimed at achieving more efficient and resilient production and consumption systems that preserve resources within a continuous cycle by optimising their value (Ellen MacArthur Foundation, 2017; Murray et al., 2017; Prieto-Sandoval, Jaca, et al., 2018). Thus, among the numerous definitions of CE proposed in the literature, some authors understand CE as a model with the objective focused on a closed-loop material flow (Kama, 2015; Li et al., 2010; Yuan et al., 2006)) while others focus on economic aspects, defining it as an economy integrated with resources, environmental factors and territoriality (Andersen, 2006; Ellen MacArthur Foundation & Granta Design, 2015).

In short, this new economic paradigm implied by CE requires a change of vision which is both corporate and individual, and which involves rethinking ways of producing and consuming. Various authors (Kirchherr et al., 2017; Mathews & Tan, 2011; Saidani et al., 2017) have established three stages of analysis in the field of CE. The upper, so-called "macro" stage includes the national and supranational level, where the government works on promoting recycling and a circularity-oriented society which includes cities and states. The intermediate, "meso" stage deals with local experiences of industrial symbiosis and eco-parks. The "micro" stage refers to companies and organisations and the CE objectives are mainly focused on making production more environmentally sustainable.

The December 2019 Eurobarometer survey revealed that 80% of citizens believe that industry is not doing enough to protect the environment, rising to 90% for Spanish citizens. The July 2020 edition also found that Europeans continue to identify the development of renewable energy and the fight against plastic waste as top priorities: 36% percent believe that the main priority should be to promote CE, and 31% think that reducing energy consumption should be the top priority. Thus, companies in general, and the manufacturing sector in particular, have a significant role to play in this process of transition towards CE due to the impact their activities have on the environment. Identifying and highlighting the progress companies are making in different regions is a necessary starting point in order to attract new initiatives to help shape a better framework with which to encourage more circular business strategies. In the process of transitioning towards a CE model, companies face similar challenges and opportunities (Agyemang et al., 2019; Geng & Doberstein, 2008; Mura et al., 2020; Ormazabal et al., 2018; Shi et al., 2008). However, their motivation for moving in this direction and the incentives they pursue may differ, depending on the particular sector and its geographical scope (Bassi & Dias, 2019). Companies should consider that there are other ways of approaching business beyond the traditional ones, not only to be more sustainable (Schöggl et al., 2020), but also more competitive and innovative. They should therefore analyse the optimal route and the potential benefits that the circular transition can offer them (Mura et al., 2020; Thorley et al., 2019). Despite the existence of circularity opportunities along the entire value chain, it is important to incentivise all developments that have positive impacts, even if they only affect part of the value chain initially, or only integrate some, rather than all possible actors.

Public incentives promote the adoption of circular practices within companies (Despeisse et al., 2015; Fischer & Pascucci, 2017; Fletcher et al., 2018; Gharfalkar et al., 2015; Ghisellini et al., 2018; Hu et al., 2018; Moktadir et al., 2018; Testa et al., 2016; Zink & Geyer, 2017), but it is new circular business models such as circular sourcing, resource recovery, product life extension, or platform and product-as-a-service sharing (Lacy & Rutqvist, 2015) that companies should focus their interest on, and see them as business opportunities to increase their revenues in this area. New digital technologies such as social media, cloud computing, analytics and mobility (Accenture Strategy, 2015) are also delivering unprecedented levels of speed and flexibility. By virture of these business models and technologies, companies can approach circular advantage from the customer's point of view, and not only from the perspective of sustainability.

3.2.2 Measuring the implementation of the CE at micro level

Measuring or assessing levels of CE implementation at a business level is a complex task (Harris et al., 2021) because of the absence of standard indicators to track progress on circularity (Rincón-Moreno et al., 2021). A number of studies have developed micro level indicators of circularity (Kristensen et al., 2021; Linder et al., 2017; Mitchell et al., 2020; Rossi et al., 2020; Walker et al., 2018). Various proposals for models to measure circularity activities or practices in companies have also been identified, and all of them list circular initiatives (Masi et al., 2017; Mura et al., 2020) or try to group these concrete circularity actions into key characteristics (European Environment Agency, 2016), fields of action (Ormazabal et al., 2018; Prieto-Sandoval, Ormazabal, et al., 2018), factors (Garza-Reyes et al., 2019), levels (Aranda-Usón et al., 2020), dimensions (Fonseca et al., 2018) or processes (Rizos et al., 2016). Some of these models have been used to measure the degree to which CE has been adopted by businesses at both national and regional level (see Table 1). Nonetheless, there is still no consensus in academia on how circularity should be measured at the micro level.

Table 1. Empirical research on CE implementation in firms

Reference	Country (Region)	No. Companies / Sector	Methods
Colucci and Vecchi 2021	Italy	4 / Fashion industry	Case study
Brydges 2021	Sweden	19 / Fashion industry	Interview
Saha, Dey, and Papagiannaki 2021	Bangladesh, Vietnam, India	114 / Textile and clothing industry	Survey
Aranda-Usón et al. 2020	Spain (Aragón)	52 / Food, Industry, Manufacturig, Waste, Service, Transport and Logistics	Interview
Barreiro-Gen and Lozano 2020	Global Reporting Initiative Data base	256	Survey
Barón et al., 2020	Spain (Catalonia)	31(SME) / Industry	EMAS Statement Review
Elia, Gnoni, and Tornese 2020	Ellen MacArthur Foundation Data base	96	Case study
Dey et al. 2020	UK (West Midlands)	130 (SME) / Manufacturing	Case study/Survey/Focus group
Mura et al. 2020	Italy	254 (SME) / Manufacturing, Tourism, Hum services, Plant engineering, ICT	Interview/Survey/Focus group
Trigkas et al. 2020	Greece	32 Leading companies	Survey
Janik and Ryszko 2019	Poland	66	EMAS Statement Review
Fonseca et al. 2018	Portugal	99	Survey

Oncioiu et al., 2018	Romania	384 (SME) / Agriculture, forestry, fishing, Industry, Constructin, Trade, Hotels and restaurants, Transport, Other services	Survey
Ormazabal et al. 2018	Spain (Navarra - Basque Country)	95	Survey
Botezat et al. 2018	Romania	98 / Industry	Survey
Ormazabal et al. 2016	Spain (Basque Country)	17 (SME) / Industry	Case study

This study follows the model proposed by Prieto-Sandoval, Ormazabal, et al. (2018) as we considered it the most appropriate for analysing the CE initiatives and actions of manufacturing companies in Spain, thus fulfilling the aim of the study: to relate CE adoption to EMS implementation through an analysis of the life cycle of products. This model defines CE as a cyclical flow that involves extracting, transforming, distributing, using and recovering materials and energy from products and services. The model proposes assessing circularity at the micro level through five fields of action covering a product's life cycle, from extracting raw materials to recovery of materials at the end of their life: Take, Make, Distribute, Use and Recover.

If the definition of CE is now approached from the perspective of an integrated economy with resources, environmental factors and territoriality (Ellen MacArthur Foundation, 2015), then business initiatives related to industrial symbiosis also need to be analysed. This concept builds on industrial metabolism to close loops across different value chains and engage traditionally separate industries in a collective approach to competitive advantage and involves the physical exchange of materials, energy, water and/or by-products (Marchi et al., 2017). Industrial symbiosis has been widely documented and applied in ecosystems within firms (Domenech et al., 2019; Mallawaarachchi et al., 2020; Rincón-Moreno et al., 2021; Wen & Meng, 2015). This study thus encompasses industrial symbiosis as a further field of action with which to evaluate companies' circular initiatives. Table 2 describes the circular practices or initiatives contemplated in the theoretical model proposed by the authors of this study for each field of action.

Table 2. Circular initiatives in the fields of action model

Fields of action	Circular Initiative
Take	Incorporating resources from the environment, making more efficient and responsible use of biological and technical resources. This includes the selection of suppliers and materials with environmental criteria as well as certifications and labels
Make	Developing the best technological practices and ecological innovations (eco-innovations) so that both the product/service and the process are carried out in the most sustainable way possible
Distribute	How the product/service is delivered to the customer (traceability and reducing environmental impact). Includes reverse logistics

Use	Reducing the energy consumption associated with using the product or the efficiency of the product itself (allowing customers to return the product after use or the development of business models where the final consumer is not the owner of the goods)
Recover	Recovering waste as a biological resource that can be returned to the biosphere or as a technical resource that can be reincorporated into an industrial process.
Industrial Symbiosis	Establishing synergies of exchange and exploitation between industries with the aim of producing a beneficial relationship for the industries involved (e.g. reusing outflows from a particular industry as raw material for another industry, or putting common services, infrastructures and/or projects into effect)

3.2.3 Environmental management systems

A management system is a formal methodology, or framework, that helps companies control and continuously improve their processes. Its aim is to achieve better results through actions and decision-making based on data and facts. EMS is the management system to use if the objective is business sustainability and reducing the environmental impact of products and processes.

The Pact for a Circular Economy (European Commission, 2015) has guidelines aimed at increasing innovation and overall efficiency of production processes through measures such as EMS implementation. Since the Pact was formed, the adoption of certifiable EMSs among companies and institutions has been remarkable (Chiarini, 2017; Daddi et al., 2015; Matuszak-Flejszman et al., 2019), and a number of studies have have been published highlighting their strengths and weaknesses (Barón et al., 2020; Boiral et al., 2018; Daddi et al., 2016; Heras-Saizarbitoria et al., 2016; Merli & Preziosi, 2018; Testa et al., 2016, 2018). Two EMS models exist at European level: the ISO 14001 standard and the Eco-Management and Audit Scheme EMAS; both serve as a basis for developing an effective EMS.

ISO 14001 was originally published in September 1996, and most recently revised in 2015 (International Organization for Standardization-ISO, 2015). This standard is defined as an overall management system that includes the organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for preparing and implementing a company's environmental policy (and also for reviewing and maintaining that policy in the future). The standard is not intended to measure the environmental impact of companies that have implemented it, but rather sets out methods for systematising and formalising environmentally sound procedures. Consequently, ISO 14000 is more about procedures than targets or results.

EMAS was first introduced in 1993, one year after the Rio Summit, where the United Nations Commission for Sustainable Development was established, and still continues as a benchmark of excellence for EMSs today. Over the years, the scheme has evolved by working hand in hand with organisations, adapting to their needs and expectations and changes in

European policies and strategies. It has undergone four revisions, the last in January 2019 (European Commission, 2018). The benefits of adopting a circular model are realised by considering the context and stakeholders; identifying environmental aspects and legal requirements, and associated risks and opportunities; and, in short, adopting a life-cycle perspective and risk-based thinking. Furthermore, it enables organisations to ensure legal compliance and anticipate the adoption of new environmental requirements, which helps minimise risks and identify new business opportunities. Under EMAS, organisations are required to demonstrate continuous improvement in their environmental performance on an ongoing basis. It enables the organisation to investigate resource efficiency, process changes, search for less polluting materials, and other actions that are drivers of innovation. The annual publication of the environmental statement also gives EMAS organisations an opportunity to achieve greater transparency. This additional effort compared to ISO 14001, for example, is recognised by all stakeholders, including public administrations. This is what makes it a very powerful communication tool which can be used to highlight actions taken in order to move towards circular model. It also sets an example for other organisations, showing them the benefits of adopting the principles of the CE. Both EMS models emphasise a life-cycle perspective of products and services that is fundamental to companies if they are to adopt circular initiatives.

3.2.4 Research hypothesis

Although research has been carried out in the field of EMS implementation, the authors have not found any studies that explore wether there is a direct relationship between those implementation and CE adoption in firms. Thus, in relation to implementing EMS and adopting CE initiatives in manufacturing companies, we proposed to test the following hypothesis:

H1: There is a correlation between the implementation of EMS and a higher adoption of CE initiatives in Spanish manufacturing companies.

Based on the proposed theoretical model, two subordinate hypotheses were proposed:

- Hypothesis H1.1: There is a correlation between EMS implementation and the adoption of circular initiatives in the five fields of action covering the product life cycle.
- Hypothesis H1.2: There is a correlation between the implementation of EMS and the adoption of business initiatives related to industrial symbiosis.

3.3 Methodology

With the aim of addressing the research questions this section describes the methodology used for the testing of the hypotheses.

3.3.1 Study sample

The empirical data used to test the hypotheses were collected from the Spanish sub-sample of the 2018 European Manufacturing Survey. This is an international questionnaire developed by the Fraunhofer Institute for Systems and Innovation Research (ISI) in 1993 (Lay & Maloca, 2004) that has been updated every two years since then. The Survey assesses the adoption of circular initiatives by manufacturing companies together with other aspects of business innovation. In 2018, the survey received 3,985 responses from 14 European countries (Austria, Croatia, Denmark, Germany, Lithuania, Netherlands, Norway, Portugal, Serbia, Slovakia, Slovenia, Spain, Sweden, and Switzerland). The Spanish survey sample comprised manufacturing establishments (NACE codes 10-33) with at least 20 employees. In total, 15,068 Spanish enterprises from the National Statistics Institute met these requirements. A questionnaire was sent both by post and telematically to the top management of approximately 27% of these companies (4000 surveys), followed by a phone-call a week later. After the initial e-mail, a remainder mail was sent two times (after one and three months). The final dataset consisted of 85 responses, with a confidence level of 80%, taking into account a margin of error of 7% (p=q=0.7). The response rate may be attributed to the length and the complexity of the questionnaire. These results impose precaution for generalizing the conclusions and stresses the exploratory nature of the performed research. Table 3 shows some descriptive statistics of the responses.

Table 3. Sample description

	No Companies	%
No. Employees		
SME <250	80	94.10%
Large >250	5	5.90%
Sector (NACE Code)		
Manufacture of food, beverages products (10-11)	16	18.80%
Manufacture of textiles, wearing apparel, leather and related products (13-15)	8	9.40%
Manufacture of wood and of products of wood and cork and furniture (16, 31)	9	10.60%
Manufacture of paper, chemical, pharmaceutical products (17-21)	7	8.20%
Manufacture of plastic and non-metallic mineral products (22-23)	6	7.10%
Manufacture of fabricated metal products, except machinery and equipment and basic metals (24-25)	6	7.10%
Manufacture of computer, electronic and optical products, electrical equipment and machinery and equipment (26, 28)	10	11.80%
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment (29-30)	3	3.50%
Other manufacturing (32)	20	23.50%
EMS Certification		
Yes	43	50.59%
No	39	45.88%
N/A	3	3.53%
Total	85	

3.3.2 Measurement

The European Manufacturing Survey covers the implementation of EMS. Thus, the companies were asked directly whether they had an EMS (ISO 14001 or EMAS). This detailed, specific question enabled the authors of the present study to classify companies into two groups according to EMS implementation: companies with an EMS, or in the process of implementation; and companies with no EMS.The survey also asked questions about various practices or initiatives associated with CE. Several of these were of interest for the present study and have been taken as variables. From the survey questions, 22 variables were chosen for analysis. The first variable is "Intensity in CE practices adoption" (IA), which seeks to determine the impact of the EMS on the adoption of CE practices. For this variable, 9 degrees of intensity were defined, with 9 being the highest and 0 the lowest. The one-way ANOVA test was used for the analysis since these are continuous scale variables. For the other 21 variables a cross-tabulation and Pearson's Chi-Square were used in the statistical analysis as it was a homogeneous random sample with dichotomous variables, proceeding to the statistical treatment of the data with the SPSS v25 programme. Table 4 classifies the variables in relation to the fields of action of the proposed theoretical model.

Table 4. Variables for measuring circular initiatives in the European Manufacturing Survey

Fields of action	#	Measurement variables of circular initiatives
Take	T1	Use of reused and/or recycled raw materials
	T2	Technologies for recycling and reuse of water
Make	M1	Integration of best sustainable manufacturing technologies
	M2	Implementation of energy management systems
	M3	Implementation of life cycle assessment tools
	M4	Introduction of technological improvements
	M5	Design aimed at extending product lifetime
Distribute	D1	Cooperation in distribution processes
	D2	Product end-of-life service - reverse logistics
Use	U1	Products with reduced energy consumption during use
	U2	Products with reduced environmental pollution during use
	U3	Products with ease of maintenance or retrofitting
	U4	Product maintenance and repair services
	U5	Product refurbishment and modernisation services
	U6	Product, machinery, or equipment rental services
Recover	R1	Kinetic and process energy recovery
	R2	Introduction of recycling/recovery improvements
Industrial Symbiosis	IS1	Joint purchasing
	IS2	Production cooperation
	IS3	Cooperation in service
	IS4	R&D cooperation with other companies

3.4 Results

The main highlights are shown in Figure 1, Figure 2 and Table 5.

In relation to the descriptive analysis of the results obtained, these show that of the 6 fields of action contemplated in the theoretical reference model, Take is the one in which most companies are working (see Figure 1), followed by business initiatives related to Industrial Symbiosis. The field of action in which less firms are working on is the one related to Recover.

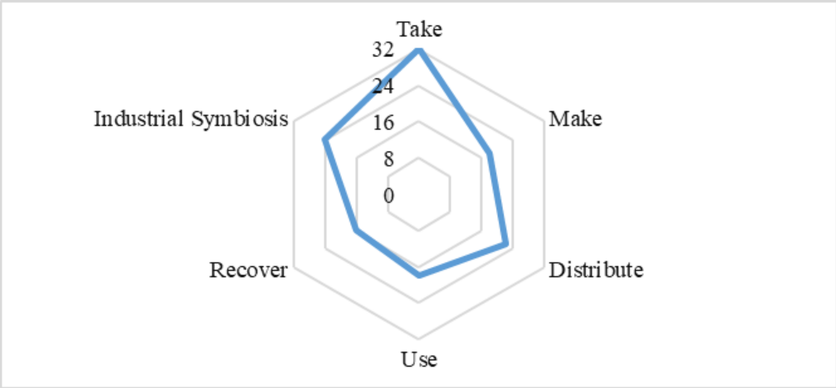

Figure 1. CE adoption related to the Fields of action model

Figure 2 shows that the circular practice most adopted by the companies in the study is related to the introduction of technological improvements (M4) with 58% of response rate, related to the use of new materials and changes in the production system at the Make stage of the product life cycle. This is followed by practices related to the use of reused and recycled raw materials (T1) at the Take stage, the product maintenance and repair services (U4) at the Use stage, both with 35% of response rate, the R&D cooperation with other companies (IS4) related to Industrial Symbiosis with 33% and finally, practices related to the cooperation with other companies in distribution processes (D1) with 32% at the Distribute stage.

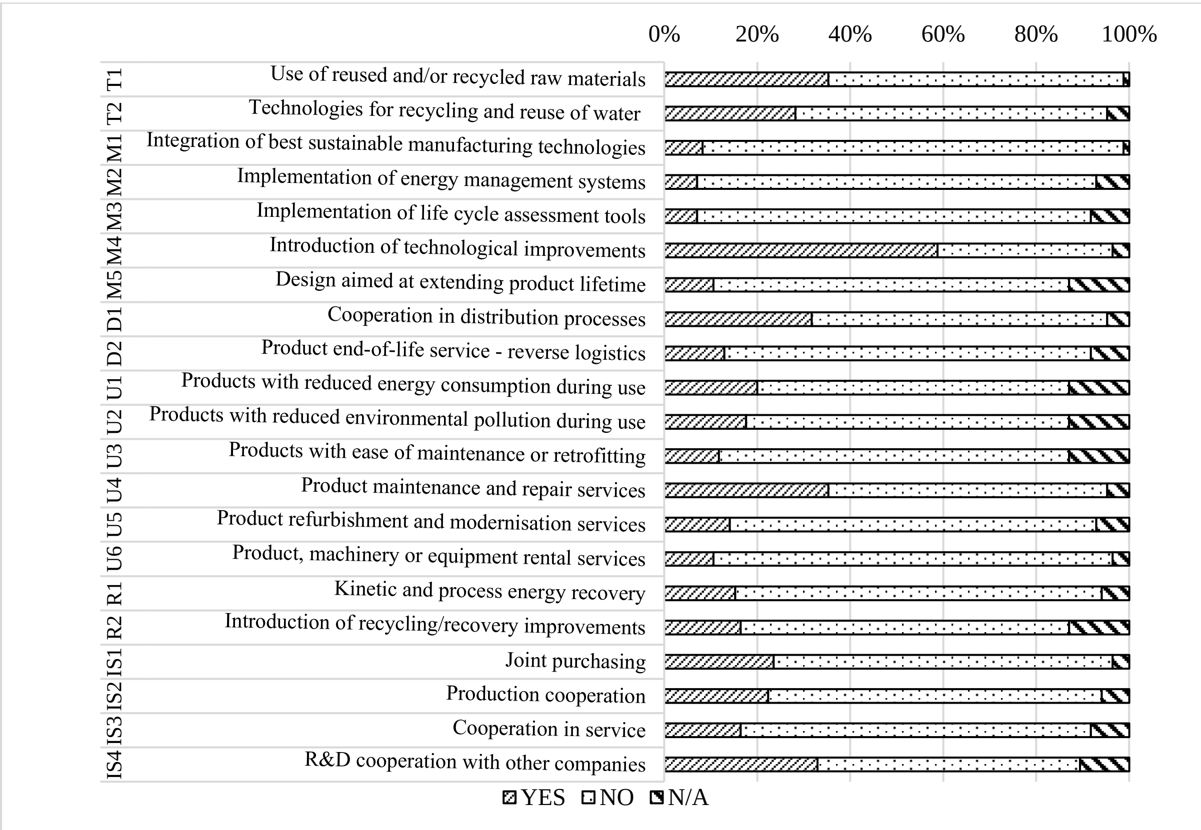

Figure 2. Circular Economy practices adoption

For the variable of Intensity of adoption (IA) in CE practices Table 5 shows a correlation between EMS adoption and the intensity of adoption of circular practices, which supports hypothesis H1.

Table 5. Correlation between EMS adoption and the intensity of adoption (IA) of circular practices

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	34.442	1	34.442	7.877	0.006*
Within Groups	341.046	78	4.372		
Total	375.488	79			

*: The correlation is significant at the 0.05 level (p<0.05)

On the other hand, for the dichotomous variables (see Table 6) a correlation is observed between the implementation of EMS and the actions that take place at the Make stage of the product life cycle, particularly in relation to practices related to the Implementation of energy management systems (M2), Implementation of life cycle assessment tools (M3) and the Introduction of technological improvements (M4). A correlation is also observed between EMS and the field of action Use, but only in the practice related with the development of Products with reduced energy consumption during use (U1). This means that hypothesis H1.1 is only partially supported. The results do not support hypothesis H1.2, and no correlation was found between EMS adoption and experiences of Industrial symbiosis.

Table 6. Correlation between EMS implementation and the adoption of circular initiatives

Var	Description	Chi-Square	Sig
T1	Use of reused and/or recycled raw materials	-0.062	0.582
T2	Technologies for recycling and reuse of water	0.093	0.413
M1	Integration of best sustainable manufacturing technologies	0.082	0.676
M2	Implementation of energy management systems	.283*	0.011*
M3	Implementation of life cycle assessment tools	.289*	0.01*
M4	Introduction of technological improvements	0.220	0.05*
M5	Design aimed at extending product lifetime	-0.321	0.068
D1	Cooperation in distribution processes	-0.106	0.351
D2	Product end-of-life service - reverse logistics	0.027	0.82
U1	Products with reduced energy consumption during use	.355*	0.042*
U2	Products with reduced environmental pollution during use	-0.184	0.305
U3	Products with ease of maintenance or retrofitting	0.050	0.783
U4	Product maintenance and repair services	0.022	0.844
U5	Product refurbishment and modernisation services	0.055	0.635
U6	Product, machinery, or equipment rental services	-0.137	0.227
R1	Kinetic and process energy recovery	0.154	0.176
R2	Introduction of recycling/recovery improvements	-0.012	0.949
IS1	Joint purchasing	0.170	0.129
IS2	Production cooperation	0.001	0.99
IS3	Cooperation in service	-0.036	0.754
IS4	R&D cooperation with other companies	0.213	0.065

*: The correlation is significant at the 0.05 level (p<0.05)

3.5 Discussion and Conclusions

This study analysed the relationship between the implementation of EMS by manufacturing companies in Spain and the adoption of CE initiatives. The results of the study provide an affirmative answer to the research question posed, indicating that companies which have implemented EMS show a higher degree of adoption of circularity practices than those which have not implemented this type of management system.

In relation to the fields of action covering the product life cycle, findings also show that only the Make field has a clear correlation with the adoption of EMS, i.e. adopting EMS favourably influences taking up circular initiatives in the field of development of best technological practices and eco-innovations so that both the product and the process are carried out in the most sustainable way possible. No relationship was found between adopting EMS and establising synergies between industries. It can therefore be concluded that as a management tool, the influence of EMS remains weak with regard to helping companies in the areas efficient and responsible use of resources; distribution and reverse logistics; actions associated with the impacts of product use and recovery; and collaborative practices between companies.

The results of the study can also help public authorities and policy makers to develop specific plans to encourage organizations to insert more circularity into EMS, for example when preparing the environmental report or statement firms could include its CE strategy and clear indicators related to the CE. Public authorities could also reward firms with EMS primarily through regulatory relief, to encourage the spread of circular economy and best environmental practices at the same time as highlight the opportunities for stakeholders to collaborate and help ensure that the future economy is, indeed, circular.

The main contribution of this paper to the academic literature is to explore wheter there is a direct relationship between the EMS certification and CE implementation in firms. One of the main limitations that this study bears is the response rate obtained. A larger sample of participating firms could produce more representative results. The second limitation regards to the fact that the study reflects the Spanish business environment and the specific socioeconomic framework. Also, a sector analysis would allow further progress in determining the role of environmental certifications and CE practices adoption as each industry sets different priority issues algon their value chains. As indicated in literature review to the best of our knowledge there is no empirical evidence on this topic, so the present paper tries to investigate this research gap. Furthermore, similar research should be applied to analyse other countries in order to assess whether similarities or differences exist according to parameters such as country, company size or sector.

References

Accenture Strategy. (2015). *Insights circular advantatges*. https://www.accenture.com/es-es/insight-circular-advantage-innovative-business-models-value-growth

Agyemang, M., Kusi-Sarpong, S., Khan, S. A., Mani, V., Rehman, S. T., & Kusi-Sarpong, H. (2019). Drivers and barriers to circular economy implementation: An explorative study in Pakistan's automobile industry. *Management Decision*, *57*(4), 971–994. https://doi.org/10.1108/MD-11-2018-1178

Álvarez-García, J., del Río-Rama, M. de la C., Saraiva, M., & Ramos Pires, A. (2018). The influence of motivations and barriers in the benefits. An empirical study of EMAS certified business in Spain. *Journal of Cleaner Production*, *185*, 62–74. https://doi.org/10.1016/j.jclepro.2018.03.023

Andersen, M. S. (2006). An introductory note on the environmental economics of the circular economy. *Sustainability Science*, *2*(1), 133–140. https://doi.org/10.1007/s11625-006-0013-6

Aranda-Usón, A., Portillo-Tarragona, P., Scarpellini, S., & Llena-Macarulla, F. (2020). The progressive adoption of a circular economy by businesses for cleaner production: An approach from a regional study in Spain. *Journal of Cleaner Production*, *247*. https://doi.org/10.1016/j.jclepro.2019.119648

Barón, A., de Castro, R., & Giménez, G. (2020). Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain. *Sustainability*, *12*(21), 9011. https://doi.org/10.3390/su12219011

Barreiro-Gen, M., & Lozano, R. (2020). How circular is the circular economy? Analysing the implementation of circular economy in organisations. *Business Strategy and the Environment*, *29*(8), 3484–3494. https://doi.org/10.1002/bse.2590

Bassi, F., & Dias, J. G. (2019). The use of circular economy practices in SMEs across the EU. *Resources, Conservation and Recycling*, *146*(March), 523–533. https://doi.org/10.1016/j.resconrec.2019.03.019

Boiral, O., Guillaumie, L., Heras-Saizarbitoria, I., & Tayo Tene, C. V. (2018). Adoption and Outcomes of ISO 14001: A Systematic Review. *International Journal of Management Reviews*, *20*(2), 411–432. https://doi.org/10.1111/ijmr.12139

Botezat, E., Dodescu, A., Văduva, S., & Fotea, S. (2018). An Exploration of Circular Economy Practices and Performance Among Romanian Producers. *Sustainability*, *10*(9), 3191. https://doi.org/10.3390/su10093191

Bravi, L., Santos, G., Pagano, A., & Murmura, F. (2020). Environmental management system according to ISO 14001:2015 as a driver to sustainable development. *Corporate Social Responsibility and Environmental Management*, *27*(6), 2599–2614. https://doi.org/10.1002/csr.1985

Brydges, T. (2021). Closing the loop on take, make, waste: Investigating circular economy practices in the Swedish fashion industry. *Journal of Cleaner Production*, *293*. https://doi.org/10.1016/j.jclepro.2021.126245

BSI Standards Publication. (2017). *Framework for implementing the principles of the circular economy in organizations – Guide*.

Chiarini, A. (2017). Setting Strategies outside a Typical Environmental Perspective Using ISO 14001 Certification. *Business Strategy and the Environment*, *26*(6), 844–854. https://doi.org/10.1002/bse.1969

Colucci, M., & Vecchi, A. (2021). Close the loop: Evidence on the implementation of the circular economy from the Italian fashion industry. *Business Strategy and the Environment*, *30*(2), 856–873. https://doi.org/10.1002/bse.2658

Daddi, T., Iraldo, F., & Testa, F. (2015). Environmental certification for organisations and products: Management approaches and operational tools. In *Environmental Certification for Organisations and Products: Management Approaches and Operational Tools*. Taylor and Francis Inc. https://doi.org/10.4324/9781315768182

Daddi, T., Testa, F., Frey, M., & Iraldo, F. (2016). Exploring the link between institutional pressures and environmental management systems effectiveness: An empirical study. *Journal of Environmental Management*, *183*, 647–656. https://doi.org/10.1016/j.jenvman.2016.09.025

Despeisse, M., Kishita, Y., Nakano, M., & Barwood, M. (2015). Towards a circular economy for end-of-life vehicles: A comparative study UK - Japan. *Procedia CIRP*, *29*, 668–673. https://doi.org/10.1016/j.procir.2015.02.122

Dey, P. K., Malesios, C., De, D., Budhwar, P., Chowdhury, S., & Cheffi, W. (2020). Circular economy to enhance sustainability of small and medium-sized enterprises. *Business Strategy and the Environment*, *29*(6), 2145–2169. https://doi.org/10.1002/bse.2492

Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., & Roman, L. (2019). Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. *Resources, Conservation and Recycling*, *141*, 76–98. https://doi.org/10.1016/j.resconrec.2018.09.016

Elia, V., Gnoni, M. G., & Tornese, F. (2020). Evaluating the adoption of circular economy practices in industrial supply chains: An empirical analysis. *Journal of Cleaner Production*, *273*, 122966. https://doi.org/10.1016/j.jclepro.2020.122966

Ellen MacArthur Foundation. (2017). Achieving 'Growth' Within. *Ellen MacArthur Foundation*, 149. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Achieving-Growth-Within-20-01-17.pdf

Ellen MacArthur Foundation, & Granta Design. (2015). Circularity Indicators: An Approach to Measuring Circularity. In *Ellen MacArthur Foundation*. https://doi.org/10.1016/j.giq.2006.04.004

European Comission. (2017). Moving towards a circular economy with EMAS. In *Circular Economy Strategy. Roadmap*. https://doi.org/10.2779/463312

European Commission. (2015). *Closing the loop - An EU action plan for the Circular Economy*.

European Commission. (2018). COMMISSION REGULATION (EU) 2018/2026 of 19 December 2018 amending Annex IV to Regulation (EC) No 1221/2009 of the European Parliament and of the Council on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS). *European Commission*, *2016*(68), 48–119. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R2026

European Commission. (2019). The European Green Deal. In *European Commission* (Vol. 53, Issue 9). https://doi.org/10.1017/CBO9781107415324.004

European Environment Agency. (2016). Circular economy in Europe: Developing the knowledge base. In *European Environment agency* (Issue 2). https://doi.org/10.2800/51444

Evans, L., Nuttall, C., Gandy, S., Iraldo, F., Barberio, M., Paglialunga, A., Gasbarro, F., & Iefe, B. N. (2015). *Project to Support the Evaluation of the Implementation of the EU Ecolabel Regulation* (Issue October). https://doi.org/10.2779/358489

Fischer, A., & Pascucci, S. (2017). Institutional incentives in circular economy transition: The case of material use in the Dutch textile industry. *Journal of Cleaner Production*, *155*, 17–32. https://doi.org/10.1016/j.jclepro.2016.12.038

Fletcher, C. A., Hooper, P. D., & Dunk, R. M. (2018). Unintended consequences of secondary legislation: A case study of the UK landfill tax (qualifying fines) order 2015. *Resources, Conservation and Recycling*, *138*, 160–171. https://doi.org/10.1016/j.resconrec.2018.07.011

Fonseca, L. M., Domingues, J. P., Pereira, M. T., Martins, F. F., & Zimon, D. (2018). Assessment of circular economy within Portuguese organizations. *Sustainability (Switzerland)*, *10*(7), 1–24. https://doi.org/10.3390/su10072521

Garza-Reyes, J. A., Salomé Valls, A., Peter Nadeem, S., Anosike, A., & Kumar, V. (2019). A circularity measurement toolkit for manufacturing SMEs. *International Journal of Production Research*, *57*(23), 7319–7343. https://doi.org/10.1080/00207543.2018.1559961

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'. *International Journal of Sustainable Development and World Ecology*, *15*(3), 231–239. https://doi.org/10.3843/SusDev.15.3:6

Gharfalkar, M., Court, R., Campbell, C., Ali, Z., & Hillier, G. (2015). Analysis of waste hierarchy in the European waste directive 2008/98/EC. *Waste Management*, *39*, 305–313. https://doi.org/10.1016/j.wasman.2015.02.007

Ghisellini, P., Ji, X., Liu, G., & Ulgiati, S. (2018). Evaluating the transition towards cleaner production in the construction and demolition sector of China: A review. *Journal of Cleaner Production*, *195*, 418–434. https://doi.org/10.1016/j.jclepro.2018.05.084

Giménez, G., Casadesús, M., & Valls, J. (2003). Using environmental management systems to increase firms' competitiveness. *Corporate Social Responsibility and Environmental Management*, *10*(2), 101–110. https://doi.org/10.1002/csr.32

Harris, S., Martin, M., & Diener, D. (2021). Circularity for circularity's sake? Scoping review of assessment methods for environmental performance in the circular economy. *Sustainable Production and Consumption*, *26*, 172–186. https://doi.org/10.1016/j.spc.2020.09.018

Heras-Saizarbitoria, I., Arana, G., & Boiral, O. (2016). Outcomes of Environmental Management Systems: the Role of Motivations and Firms' Characteristics. *Business Strategy and the Environment*, *25*(8), 545–559. https://doi.org/10.1002/bse.1884

Hu, Y., He, X., & Poustie, M. (2018). Can legislation promote a circular economy? A material flow-based evaluation of the circular degree of the Chinese economy. *Sustainability (Switzerland)*, *10*(4). https://doi.org/10.3390/su10040990

International Organization for Standardization-ISO. (2015). *ISO 14001:2015, Environmental management systems — Requirements with guidance for use*. ISO. https://www.iso.org/obp/ui#iso:std:iso:14001:ed-3:v1:en

Janik, A., & Ryszko, A. (2019). Circular economy in companies: an analysis of selected indicators from a managerial perspective. *Multidisciplinary Aspects of Production Engineering*, *2*(1), 523–535. https://doi.org/10.2478/mape-2019-0053

Kama, K. (2015). Circling the economy: resource-making and marketization in EU electronic waste policy. *Area*, *47*(1), 16–23. https://doi.org/10.1111/area.12143

Katz-Gerro, T., & López Sintas, J. (2018). Mapping circular economy activities in the European Union: Patterns of implementation and their correlates in small and medium-sized enterprises. *Business Strategy and the Environment*, *28*(4), bse.2259. https://doi.org/10.1002/bse.2259

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Kristensen, H. S., Mosgaard, M. A., & Remmen, A. (2021). Integrating circular principles in environmental management systems. *Journal of Cleaner Production*, *286*. https://doi.org/10.1016/j.jclepro.2020.125485

Lacy, P., & Rutqvist, J. (2015). The Sharing Platform Business Model: Sweating Idle Assets. In *Waste to Wealth* (pp. 84–98). Palgrave Macmillan UK. https://doi.org/10.1057/9781137530707_7

Lay, G., & Maloca, S. (2004). Dokumentation der Umfrage Innovationen in der Produktion 2003. In *Arbeitspaper des Fraunhofer ISI*.

Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. *Sustainability*, *8*(1), 43. https://doi.org/10.3390/su8010043

Li, H., Bao, W., Xiu, C., Zhang, Y., & Xu, H. (2010). Energy conservation and circular economy in China's process industries. *Energy*, *35*(11), 4273–4281. https://doi.org/10.1016/j.energy.2009.04.021

Linder, M., Sarasini, S., & van Loon, P. (2017). A Metric for Quantifying Product-Level Circularity. *Journal of Industrial Ecology*, *21*(3), 545–558. https://doi.org/10.1111/jiec.12552

Mallawaarachchi, H., Sandanayake, Y., Karunasena, G., & Liu, C. (2020). Unveiling the conceptual development of industrial symbiosis: Bibliometric analysis. In *Journal of Cleaner Production* (Vol. 258, p. 120618). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2020.120618

Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., & Aminoff, A. (2018). Do circular economy business models capture intended environmental value propositions? *Journal of Cleaner Production*, *171*, 413–422. https://doi.org/10.1016/j.jclepro.2017.10.003

Marchi, B., Zanoni, S., & Zavanella, L. E. (2017). Symbiosis between industrial systems, utilities and public service facilities for boosting energy and resource efficiency. *Energy Procedia*, *128*, 544–550. https://doi.org/10.1016/j.egypro.2017.09.006

Masi, D., Day, S., & Godsell, J. (2017). Supply chain configurations in the circular economy: A systematic literature review. In *Sustainability (Switzerland)* (Vol. 9, Issue 9). MDPI AG. https://doi.org/10.3390/su9091602

Mathews, J. A., & Tan, H. (2011). Progress Toward a Circular Economy in China. *Journal of Industrial Ecology*, *15*(3), 435–457. https://doi.org/10.1111/j.1530-9290.2011.00332.x

Matuszak-Flejszman, A., Szyszka, B., & Jóhannsdóttir, L. (2019). Effectiveness of EMAS: A case study of Polish organisations registered under EMAS. *Environmental Impact Assessment Review*, *74*, 86–94. https://doi.org/10.1016/j.eiar.2018.09.005

Merli, R., & Preziosi, M. (2018). The EMAS impasse: Factors influencing Italian organizations to withdraw or renew the registration. *Journal of Cleaner Production*, *172*, 4532–4543. https://doi.org/10.1016/j.jclepro.2017.11.031

Ministerio de Agricultura, A. y M. (2015). *BOE.es - BOE-A-2015-13490 Resolución de 16 de noviembre de 2015, de la Dirección General de Calidad y Evaluación Ambiental y Medio Natural, por la que se publica el Acuerdo del Consejo de Ministros de 6 de noviembre de 2015, por el que se aprueba el Plan* . «BOE» Núm. 297, de 12/12/2015. https://www.boe.es/buscar/act.php?id=BOE-A-2015-13490

Ministerio de Economía Industria y Competitividad. (2018). Circular Economy Spanish Strategy 'España Circular 2030'. In *Exacutive Summary*. https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/economia-circular/espanacircular_2030_executivesummary_en_tcm30-510578.pdf

Mitchell, S., O'Dowd, P., & Dimache, A. (2020). Manufacturing SMEs doing it for themselves: developing, testing and piloting an online sustainability and eco-innovation toolkit for SMEs. *International Journal of Sustainable Engineering*, *13*(3), 159–170. https://doi.org/10.1080/19397038.2019.1685609

Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M., & Paul, S. K. (2018). Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. *Journal of Cleaner Production*, *174*, 1366–1380. https://doi.org/10.1016/j.jclepro.2017.11.063

Mura, M., Longo, M., & Zanni, S. (2020). Circular economy in Italian SMEs: A multi-method study. *Journal of Cleaner Production*, *245*, 118821. https://doi.org/10.1016/j.jclepro.2019.118821

Murmura, F., Liberatore, L., Bravi, L., & Casolani, N. (2018). Evaluation of Italian Companies' Perception About ISO 14001 and Eco Management and Audit Scheme III: Motivations, Benefits and Barriers. *Journal of Cleaner Production*, *174*, 691–700. https://doi.org/10.1016/j.jclepro.2017.10.337

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, *140*(3), 369–380. https://doi.org/10.1007/s10551-015-2693-2

Oncioiu, I., Căpuşneanu, S., Türkeș, M., Topor, D., Constantin, D.-M., Marin-Pantelescu, A., & Ștefan Hint, M. (2018). The Sustainability of Romanian SMEs and Their Involvement in the Circular Economy. *Sustainability*, *10*(8), 2761. https://doi.org/10.3390/su10082761

Ormazabal, M., Prieto-Sandoval, V., Jaca, C., & Santos, J. (2016). An overview of the circular economy among SMEs in the Basque country: A multiple case study. *Journal of Industrial Engineering and Management*, *9*(5), 1047. https://doi.org/10.3926/jiem.2065

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., & Jaca, C. (2018). Circular Economy in Spanish SMEs: Challenges and opportunities. *Journal of Cleaner Production*, *185*, 157–167. https://doi.org/10.1016/j.jclepro.2018.03.031

Pieroni, M. P. P., McAloone, T. C., & Pigosso, D. C. A. (2019). Business model innovation for circular economy and sustainability: A review of approaches. *Journal of Cleaner Production*, *215*, 198–216. https://doi.org/10.1016/j.jclepro.2019.01.036

Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of Cleaner Production*, *179*, 605–615. https://doi.org/10.1016/j.jclepro.2017.12.224

Prieto-Sandoval, V., Ormazabal, M., Jaca, C., & Viles, E. (2018). Key elements in assessing circular economy implementation in small and medium-sized enterprises. *Business Strategy and the Environment*, *27*(8), 1525–1534. https://doi.org/10.1002/bse.2210

Rincón-Moreno, J., Ormazábal, M., Álvarez, M. J., & Jaca, C. (2021). Advancing circular economy performance indicators and their application in Spanish companies. *Journal of Cleaner Production*, *279*, 123605. https://doi.org/10.1016/j.jclepro.2020.123605

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability (Switzerland)*, *8*(11). https://doi.org/10.3390/su8111212

Rossi, E., Bertassini, A. C., dos Santos Ferreira, C., Neves do Amaral, W. A., & Ometto, A. R. (2020). Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases. *Journal of Cleaner Production*, *247*, 119137. https://doi.org/10.1016/j.jclepro.2019.119137

Saha, K., Dey, P. K., & Papagiannaki, E. (2021). Implementing circular economy in the textile and clothing industry. *Business Strategy and the Environment*, *May 2020*, 1–34. https://doi.org/10.1002/bse.2670

Saidani, M., Yannou, B., Leroy, Y., & Cluzel, F. (2017). How to Assess Product Performance in the Circular Economy? Proposed Requirements for the Design of a Circularity Measurement Framework. *Recycling*, *2*(1), 6. https://doi.org/10.3390/recycling2010006

Schöggl, J. P., Stumpf, L., & Baumgartner, R. J. (2020). The narrative of sustainability and circular economy - A longitudinal review of two decades of research. *Resources, Conservation and Recycling*, *163*(August), 105073. https://doi.org/10.1016/j.resconrec.2020.105073

Shi, H., Peng, S. Z., Liu, Y., & Zhong, P. (2008). Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. *Journal of Cleaner Production*, *16*(7), 842–852. https://doi.org/10.1016/j.jclepro.2007.05.002

Testa, F., Boiral, O., & Iraldo, F. (2018). Internalization of environmental practices and institutional complexity: Can stakeholders pressures encourage greenwashing? *Journal of Business Ethics*, *147*(2), 287–307. https://doi.org/10.1007/s10551-015-2960-2

Testa, F., Heras-Saizarbitoria, I., Daddi, T., Boiral, O., & Iraldo, F. (2016). Public regulatory relief and the adoption of environmental management systems: a European survey. *Journal of Environmental Planning and Management*, *59*(12), 2231–2250. https://doi.org/10.1080/09640568.2016.1139491

Thorley, J., Garza-Reyes, J. A., & Anosike, A. (2019). The circular economy impact on small to medium enterprises. *WIT Transactions on Ecology and the Environment*, *231*, 257–267. https://doi.org/10.2495/WM180241

Trigkas, M., Karagouni, G., Mpyrou, K., & Papadopoulos, I. (2020). Circular economy. The Greek industry leaders' way towards a transformational shift. *Resources, Conservation and Recycling*, *163*(December 2019), 105092. https://doi.org/10.1016/j.resconrec.2020.105092

Walker, S., Coleman, N., Hodgson, P., Collins, N., & Brimacombe, L. (2018). Evaluating the Environmental Dimension of Material Efficiency Strategies Relating to the Circular Economy. *Sustainability*, *10*(3), 666. https://doi.org/10.3390/su10030666

Wen, Z., & Meng, X. (2015). Quantitative assessment of industrial symbiosis for the promotion of circular economy: A case study of the printed circuit boards industry in China's Suzhou New District. *Journal of Cleaner Production*, *90*, 211–219. https://doi.org/10.1016/j.jclepro.2014.03.041

Witjes, S., & Lozano, R. (2016). Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resources, Conservation and Recycling*, *112*, 37–44. https://doi.org/10.1016/j.resconrec.2016.04.015

Yuan, Z., Bi, J., & Moriguichi, Y. (2006). The Circular Economy: A New Development Strategy in China. *Journal of Industrial Ecology*, *10*(1–2), 4–8. https://doi.org/10.1162/108819806775545321

Zink, T., & Geyer, R. (2017). Circular Economy Rebound. *Journal of Industrial Ecology*, *21*(3), 593–602. https://doi.org/10.1111/jiec.12545

Chapter 4. Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain

This chapter is based on: Barón, A., de Castro, R., Giménez, G., 2020. Circular Economy Practices among Industrial EMAS-Registered SMEs in Spain. Sustain. 12, 1–28. https://doi.org/10.3390/su1221901

CIRCULAR ECONOMY PRACTICES AMONG INDUSTRIAL EMAS-REGISTERED SMES IN SPAIN

SUSTAINABILITY

Alexanndra Barón Dorado, Rudi de Castro, Gerusa Giménez

ABSTRACT

The Eurobarometer report from December 2019 revealed that 80% of European Union (EU) citizens believe that industry is doing too little to protect the environment and that more work needs to be done to help companies transition to a more sustainable economic model. In recent years, the EU has made the Circular Economy (CE) a priority, and an environmental management system based on the EMAS Regulation can help companies achieve this goal by assisting them in analysing and measuring an efficient and sustainable use of resources. Thus, this study analyses EMAS companies' environmental statements in order to identify and quantify the CE practices they have implemented. Findings identify 23 circular practices and show that the majority of companies focus their efforts on reducing emissions by optimizing the materials cycle and improving internal production processes. Eco-design stands out as the main driver amongst the circular transformation practices. This study has also detected a lack of uniformity in the way companies quantify the various circular practices currently operating, or how they communicate this information. These results may be useful to companies, professionals and administrations responsible for promoting the CE, and it can also provide guidance on what information to include in future environmental statements.

Keywords: Circular Economy (CE); sustainability; circularity; implementation; Environmental Management System (EMS); Eco-Management and Audit Scheme (EMAS); Small and Medium Sized Enterprises (SMEs); industrial; Spain

4.1 Introduction

Neither the planet nor the economy can survive if it continues to follow the traditional economic model based on raw material extraction, manufacturing, use and disposal. Preserving valuable resources and fully exploiting their full economic value has become crucial [1]. The Circular Economy (CE) is rooted in the principles of reducing waste and protecting the environment as well as dramatically transforming the way the economy works. By rethinking the way in which we produce, work and buy products, new opportunities and occupations can be created [2,3]. The CE needs to be able to generate value which is less dependent on natural resources by taking a systemic and holistic approach and integrating the whole value chain. The concept of a CE requires, and accommodates to a greater or lesser extent, the participation of a wide spectrum of agents varying in size and nature such as public and private agents, consumers or research centres.

Aspiring to replace single-use products with ones that are circular by design and creating reverse logistic networks have become powerful stimuli for new ideas. Thus, everything related to circular supplies, resource recovery, product life extension, sharing platforms and products as a service represents a vibrant business terrain for entrepreneurs [4]. Businesses should reap the benefits of an economy that operates with higher rates of technological development, optimized and improved materials, energy efficiency and greater opportunities for productive and resource-efficient companies.

Hence, activities and actions aligned with the new CE paradigm in the business environment have become more and more frequent for all types of organisations and sectors, and increasingly, researchers are focusing their efforts on studying the key role played by businesses in developing the CE at company and organization level [5–8]. However, a more in-depth study of how businesses on the road to circularity integrate the principles of this new paradigm is needed [9,10].

Companies that have implemented an Environmental Management System (EMS) are considered to have greater environmental awareness and show a special sensitivity towards protecting the environment, as well as being one step ahead of the rest [11–13]. The Environmental Maturity Model (EMM), developed by Ormazábal et al. [14], which assesses the level of maturity of companies transitioning to a CE, ranging from the most reactive to the most proactive maturity stage, considers that companies implementing an EMS would be located at a medium stage of maturity in their progress towards circularity (Systematization) on a 6-stage scale. Traditionally, proactive EMS adoption and certification have been associated with large companies, usually endowed with more capital than small and medium-sized enterprises (SMEs), and which have a clear strategic vision and regard EMS implementation as a genuine commitment to competition [15]. However, this situation has been changing, and increasingly, SMEs are also reaping the benefits of implementing EMS in their organisations. Proof of this are the data available from the European Commission's EMAS Helpdesk register of 15 June 2020, which reveals that only 26% of EMAS-registered businesses are large companies [16]. Nevertheless, a company's green image and commitment to a paradigm shift towards the CE needs to be translated into action [17].

Research on CE adoption in companies at regional level is still limited [18], so the aim of this study is to help reduce this deficit. Therefore, this article aims to identify CE practices being reported by SMEs implementing EMS in their move towards a CE model. The following Research Questions (RQ) have been posed:

- RQ1: Do companies include the CE concept in their environmental statements?
- RQ2: What CE activities or practices do companies claim to have adopted? Are some activities more commonly adopted than others?
- RQ3: How are CE practices reported and quantified in environmental statements? How are these practices reported to stakeholders?
- RQ4: Does a relationship exist between circularity practices and economic performance?
- RQ5: What information should be included in environmental statements in the future to help evaluate the application of circularity practices in EMAS-registered companies?

The aim of this study is to answer these questions by analysing the environmental statements of EMAS-registered SMEs in Spain, currently the second country in the EU in number of companies with EMAS registration (1092 companies), behind Germany (1099 companies). Specifically, we have analysed companies from the industrial sector in Catalonia (northeast Spain), one of the most industrialized regions of Spain, with a business network mainly made up of SMEs.

This study is focused on companies in the industrial sector as the challenges of environmental pollution and worldwide scarcity of resources have meant that these companies must simultaneously cope with the pressure of environmental regulations, the challenges of resource price volatility and supply chain risks in a far more critical way [19]. At the same time, this sector has been included in the priority areas of activity on which the 2030 Spanish Strategy for the Circular Economy is focused.

The main novelty of this research is that it focuses on exploring the actions that industrial EMAS-registered SMEs have claimed to have taken in relation to adopting CE practices. These companies are supposedly located at a higher stage of circularity than the rest of industries that still have a very traditional, linear business model, as suggested by Marrucci et al. [12]. We believe this study can be useful for other companies operating in similar contexts, but which have not yet reached the mid-level maturity stage on the EMM scale developed by Ormazábal et al. [14]. Thus, this contribution aims to provide examples of practices implemented on the long road of transition towards the sustainable production and consumption model that the CE involves. Finally, this study also focuses on analysing the way in which companies quantify different circular variables, such as materials inflow and outflow, water and energy consumption, and how this information is communicated to different stakeholders.

At Spanish state level, studies analysing CE implementation have been conducted in the Basque Country and Navarra [20,21] and Aragon [22,23]. This study will help expand the geographical scope of the research by analysing the situation in Catalonia.

This article is organized into 5 sections. Section 2 reviews the literature on CE-related concepts in the field of SMEs and their relationship with EMS. Section 3 describes the methodology designed to respond to the research questions based on information in the environmental statements. The results are presented in Section 4. Finally, results analysis and the main conclusions and limitations of the study are contained in Section 5.

4.2. Overview of the Research Context

In 2015, the United Nations presented the 2030 Agenda for Sustainable Development, which established 17 Sustainable Development Goals (SDG) focusing on people, planet and prosperity. The CE is one of the central elements for achieving some of the goals, among which five are especially noteworthy:

- SDG 7: Ensure access to affordable, reliable, sustainable and modern energy.
- SDG 8: Promote inclusive and sustainable economic growth, employment and decent work for all.
- SDG 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation.
- SDG 12: Ensure sustainable consumption and production patterns.
- SDG 13: Take urgent action to combat climate change and its impacts.

Since then, the CE has been vigorously implemented in the EU Commission's economic policy with the aim of promoting the transition towards production and consumption systems based on the principles of circularity [24]. In a global context of strained, over-exploited resources, no one questions the importance of taking sustainability into account in business strategies, business models and product and service design [6,25,26]. It is the key to moving towards a more competitive, responsible and circular economy for progress and social wellbeing.

The definition of CE has been widely debated depending on the field of knowledge and the issues addressed [7,9,23,27–30], but consensus does exist that CE is an economic model oriented towards achieving more efficient and resilient production and consumption systems that preserve resources within a continuous cycle optimizing their value [31–33]. Thus, the numerous, different definitions of CE can be classified according to whether they focus on its objectives, activities or outcomes [34]. Some of these contributions are summarized briefly in Table 1.

Table 1. Contributions to the definition of Circular Economy

	EC Definition	References
Objectives	Closed flow of materials/Economy integrated with resources, environmental factors and territoriality	References [33,35–38] Yuan et al., 2006; Ellen MacArthur Foundation, 2015; Li et al., 2010; Andersen, 2007; Kama, 2015
Activities	Production processes /Industrial symbiosis	References [9,28,29,39–41] Zhijun y Nailing, 2007; Ehrenfeld y Gertler, 1997; Jacobsen, 2006; Walls and Paquin, 2015; Zeng et al. 2017; Katz et al., 2019
Outcomes	Energy efficiency/Waste minimization/Environmental conservation	References [34,42–44] Liu et al. 2009; Morlet et al., 2016; Ghisellini et al., 2016; Haas et al., 2015

In short, the new economic paradigm involving the CE requires a change in both business and individual outlook, rethinking the ways in which we produce and consume. Some authors [30,45,46] have established varying levels of analysis in the implementation of CE principles:

- Macro: includes national and supranational levels where work is being done to promote a society oriented towards recycling and circularity implemented nationally and supranationally. Includes cities and states.
- Meso: contemplates CE implementation through eco-parks, local industrial symbiosis initiatives and through the management of waste and the inflow and outflow of resources and raw materials in a territory.
- Micro: refers to companies and organisations and consumers. CE objectives for this level are focused mainly on more environmentally sustainable production.
- Nano: at process or product level.

Thus, this new paradigm shift should take place under a multi-level approach [47]. It should also be implemented at all levels simultaneously and always within the framework of the Triple Bottom Line perspective [48], which intersects economic aspects with social and environmental ones [39].

4.2.1. Adopting the Circular Economy in SMEs

According to the results of a new Eurobarometer survey (December 2019), 94% of citizens from all EU Member States said that protecting the environment was important for them. Ninety-one percent stated that climate change was a serious problem in the EU, and 80% of respondents, reaching 90% in the case of Spain, felt that industry was not doing enough to protect the environment. The survey also revealed that citizens believed responsibility should be shared by large companies and industry, national governments and the EU, as well as by the citizens themselves. It was recognized that fundamental changes may be needed as well as greater investment in research and development, more information and education, stricter legislative control and the promotion of company participation in sustainable activities.

SMEs play a fundamental role in the transition to a CE both at global and European level and in Spain, where they represent 99.83% of all companies [49]. Thus, SMEs are essential drivers for the transition towards a CE. Identifying all the opportunities gained and progress made by these companies in different territories in this field and highlighting their importance is a necessary starting point to attract new initiatives to help shape an environment that fosters more CE business strategies.

Challenges and opportunities for companies in their transition towards a CE model have been identified in different studies [47,50–54]. On this basis, it must be taken into account that business incentives and motivation to move forward in this direction may differ greatly, both qualitatively and quantitatively, depending on the sector, the company and its location [55]. In some cases, the focus will be on transforming existing business activities, while in others, new business models will have to be introduced for which there may be no precedent. It is also important to keep in mind that, although circularity may exist across the entire value chain, it is possible that in the early stages of implementing the new circularity paradigm, all progress with positive impacts should be recognized and encouraged, even though only one part of the value chain is affected and only a part of the possible stakeholders have been integrated.

It is well known that SMEs have a daily work routine that is packed with obligations, and they are very focused on their business, but they should take a moment to reflect on what routes to take and the possible benefits that transitioning to the CE can bring them [52,56,57]. Aside from traditional ways of approaching business, many other ways exist and being more sustainable is not the only reason for making this transition, but also being more competitive, having a mid- to long-term plan, or being innovative, to name but a few.

Some public incentives can help promote the adoption of sustainable CE manufacturing practices among SMEs [58–66]. Promoting the introduction of broader circular principles related to the exchange of goods and services through polices supporting corporate social responsibility is also useful [67].

At a European level, there are the European Structural and Investment Funds, the SME Instrument, or Fast Track to Innovation [24]. In Spain, the 2030 Spanish Circular Economy Strategy was passed on 2 June 2020, in line with the objectives of the two European Commission Circular Economy Action Plans: (1) Closing the loop: an EU action plan for the Circular Economy, and (2) A New Circular Economy Action Plan for a Cleaner and more Competitive Europe (2020) in addition to the European Green Deal and the 2030 Agenda for Sustainable Development. At the level of Catalonia, the Government of Catalonia Strategy for Promoting Green and Circular Economy in Catalonia and the Catalan Eco-design Strategy have been created to promote a CE based on eco-innovation. The PIMEC business organization has also approved its own strategy for promoting a green and CE.

However, apart from the support that SMEs can obtain through the state, regional governments or business associations, it is worth highlighting where business opportunities can be found, so SMEs can focus on increasing their income in this area. Lacy and Rutqvist [68] identified five circular business models (Circular Supplies, Resource Recovery, Product Life Extension, Sharing Platforms and Product as a Service), and the consulting firm Accenture [56] highlighted 10 technologies (in particular, digital technologies in the form of social networks, cloud computing, analytics and mobility), which are enabling levels of speed and flexibility not seen before. Thanks to these business models and technologies, companies can focus on circular advantage from the customer's point of view instead of on simply improving efficiency.

4.2.2. Environmental Management Systems and the Circular Economy

The Pact for a Circular Economy [24] was spearheaded by various government entities in order to define the process of transition towards a CE model. One of its actions is to develop guidelines to boost innovation and the overall efficiency of production processes by introducing measures such as EMS. Since the Pact was written, certifiable EMS have been adopted by a significant number of businesses and institutions [69–71], and a considerable number of studies have highlighted their strengths and weaknesses [72–79]. Other institutions and researchers have also highlighted the importance of adopting environmental management standards [80] and eco-labels [81,82] to foster CE within companies.

One of the standards underpinning the transition to CE is the Eco-Management and Audit Scheme (EMAS). EMAS was developed in 1993, a year before the first version of the international standard ISO 14001 was published, and a year after the 1992 Rio Summit. At the Rio Summit, a broad intergovernmental agreement on a global action plan to promote sustainable development, called Agenda 21, was approved and the United Nations Commission for Sustainable Development was created. After 27 years, the EMAS model continues to be a reference of excellence for environmental management systems. Throughout this time, the scheme has been evolving alongside organisations, adapting to their needs and expectations, and to changes in European policies and strategies. It has undergone up to four revisions, the last one in January 2019 [83].

The EMAS Regulation can help businesses on the path towards a CE as it evaluates the environmental impact of their activities, as well as encouraging improvements in their energy efficiency and developing systematized audits. It also monitors and guarantees the transparency of their processes [80]. In essence, EMAS contributes to circular development by analysing and measuring the efficient use of resources [12,83,84].

The benefits of a circular model can be reaped by taking both the context and stakeholders into account, identifying the environmental aspects and legal requirements, as well as any associated risks and opportunities; in other words, adopting a Lifecycle perspective and risk-based thinking. In addition, a circular model enables organisations to not only ensure legal compliance but also plan ahead for new environmental requirements to be approved, which in turn contribute to minimizing risks and identifying new business opportunities.

Approaching CE implies changing the business model and incorporating new management practices. To do so, involving employees is essential. This is a long-standing requirement in the EMAS and makes employees aware of the importance of participating in the system. It is particularly important for senior management to be involved as they bear the greatest responsibility for the company's environmental strategy and can therefore demonstrate their leadership.

EMAS requires that organisations demonstrate continuous improvement in their environmental performance on an ongoing basis. This encourages the organization to investigate the efficiency of resource consumption, changes in processes, the search for less contaminating materials and other actions that are a driving force for innovation. The annual publication of the environmental statement gives EMAS organisations a major opportunity for transparency. This additional initiative, compared to the ISO 14001 standard, for example, is recognized by all interested parties, including public administrations. This is what makes it a very powerful communication tool which highlights the actions taken to move towards circular models. It also serves as an example for other organisations to verify the advantages of adopting the principles that govern the CE.

Hence, this study aims to identify the CE practices currently reported by EMAS-registered industrial sector SMEs. The question that arises at this point is what adopting a CE model means for companies in this sector. The literature refers to sustainable manufacturing as a radical change within the context of closed-loop product systems. The concept of Resource Conservative Manufacturing, ResCoM, has been introduced as a new paradigm for sustainable manufacturing [85]. Since traditional business models, products and supply chains have been designed to operate in linear systems, they are unable to cope with the dynamics of closed-loop systems. Therefore, a novel approach is proposed in which the dynamic interaction between business models, product design, supply chains and customers is essential, and at the same time treated as an integral part of industrial firms [86]. The concept of ResCoM includes the concept of multiple product lifecycles and, together with energy conservation, material and added value with waste prevention and environmental protection are integrated components of the product design and development strategy [10]. A difficulty for many SMEs is the fact that these companies often work on a B2B basis and producers cannot control the final product. The majority lose their traceability, which means that they cannot take action in the reclaiming materials stage, and this limits their actions regarding clean production practices to within the company alone [13,47].

4.2.3. Models for Measuring Micro Level Circularity Actions

In order to measure the degree to which businesses adopt CE, several studies in the literature that propose definitions of micro-level circularity indicators were identified [87–92]. Their novelty, together with the very generic definition given to them, may explain the low degree of CE adopted by businesses [93–95]. Park and Kremer [96] warn that companies need to understand the usefulness, importance and potential benefits of environmental sustainability indicators in order to be able to use them in their operations management [97]. Another key issue is obtaining the considerable amount of data these indicators require. Much of the necessary data is difficult to gather and often has to be provided by various actors linked to the product lifecycle. This difficulty in obtaining data, both in terms of time and cost, is one of the main stumbling blocks for extending the use of indicators to a company or organization level, due to the lack of information exchange between companies and confidentiality issues [98,99]. Despite this, advances in digital technology should make it easier and faster to obtain data [27]. Standards publications such as the BS8001:2017- Framework for implementing CE principles in organisations [92] should also help guide organisations in implementing the standards.

Various models proposing to measure circularity activities or practices in companies have been identified in the literature: Garza-Reyes et al. [100] carried out a review of various models used to measure CE in SMEs and proposed a model that includes 36 practices grouped into 7 factors; Masi et al. [101] mention 25 CE practices; the European Environmental Agency (EEA) [3] proposes 16 actions grouped into 5 key characteristics; Mura et al. [52] identify 20 practices; Aranda-Uson et al. [18] propose 13 activities grouped into 4 levels; Fonseca et al. [13] propose 15 dimensions; Prieto-Sandoval et al. [20] define 11 elements as fields of action for CE; Janik and Zafraniek [84] establish 12 practices grouped in the 5 categories described as key elements by the EEA [3]; and Rizos et al. [51] mention 8 main processes.

Some of these proposals have been put into practice, and the models used to measure the degree to which CE has been adopted by businesses at both national and regional level are shown in Table 2.

Table 2. Studies on EC implementation in companies

Reference	Country (Region)	Sample	Methods	Main Conclusions
Ormazábal et al., 2016 [21]]	Spain (Basque Country)	17	Case study	80% try to reduce consumption raw materials 18% water treatment or recirculate by-products 41% recovery of used products 53% no environmental criteria for supplier selection
Fonseca et al., 2018 [13]	Portugal	99	Survey	The segregation and valuation of waste is a priority The collection of end-of-life products and cooperation with suppliers and customers are no very intense

Oncioiu et al., 2018 [102]	Romania	384	Survey	14% strengthening the guarantees offered to consumers who purchase goods online 13% use of renewable energy 13% designing smart and green products and using energy labelling 10% use of advanced manufacturing facilities to achieve clean production
Ormázabal et al., 2018 [47]	Spain (Navarra -Basque Country)	95	Survey	42% try to reduce consumption raw materials Low use of ecological/biodegradable materials 17% use environmental criteria for supplier selection Not yet prepared for circular business models
Janik and Szafraniec, 2019 [84]	Poland	66	EMAS Statement Review	50% try to minimize the waste production 47% try to minimize energy and water usage Only 3% work on keeping the value of products/components/materials in the economy
Aranda-Usón et al., 2020 [18]	Spain (Aragón)	52	Interviews	Most frequently implemented activities: 82% industrial waste recycling 75% energy efficiency 60% reduction of environmental impact
Kumar et al., 2020 [103]	UK (Midlands)	130	Case study Focus group Survey	CE fields of action (Take, Make, Distribute, Use and Recover) are correlated to economic performance, Only Make and Use are related to environmental and social performance.
Mura et al., 2020 [52]	Italy	254	Interviews Survey Focus group	84% apply separated waste collection 38% apply recovery/reuse of packaging 32% work on energy conservation Only 14% work on resource saving practices

In this study, the model proposed by Prieto-Sandoval et al. [20] was followed to analyse the CE practices reported in the environmental statements. The underlying concept of this model is that CE can be understood through 5 areas of action: Take, Make, Distribute, Use and Recover. Each of these areas is specified in a series of circular practices in line with the key characteristics proposed by the EEA [3], enabling comparisons with similar studies to be made (see Table 3). We found that only 3 fields of action (Take, Make and Recover) had key related characteristics.

Table 3. Circular practices following the model of fields of action

Field of Action	Elements	EEA Key Characteristic
TAKE The way in which industries take energy and resources from the environment	Selection of biodegradable materials in different value chains	Non-renewable resources replaced with renewable ones within sustainable levels of supply
		Increased share of recyclable and recycled materials that can replace the use of virgin materials
	Selection of easy recirculated materials in different value chains	Minimised and optimised exploitation of raw materials, while delivering more value from fewer materials
		Closure of material loops
		Sustainably sourced raw materials
	Environmental efficiency of production	Reduced import dependence on natural resources
		Efficient use of natural resources
		Minimised overall energy use

	processes to reduce resources use	Minimised overall water use
	Environmental efficiency of production processes to reduce emissions	Reduced emissions throughout the full material cycle through the use of less raw material and sustainable sourcing
		Less pollution through clean material cycles
	Sustainable energy sources for production	Energy replaced with renewable ones
MAKE Processes can be carried out in a sustainable way with eco-innovations and the best technological practices	Environmental innovation in the design of sustainable products and services, in order to extend their lifecycles and facilitate recovery in the future.	Extended product lifetime keeping the value of products in use
	The recovery of raw materials and resources in the internal process of the company	–
DISTRIBUTE The way in which a product or a process is delivered to the customer	The development of a sustainable logistics systems	–
USE Refers to reduce the environmental impact associated with the use of the product	The development of business models where the final consumer is not the owner of the goods	–
	The offer of services that extended the life of the products of services	–
	Design of products that work with sustainable energies	–
RECOVER In the CE, eco-innovation processes are boosted to recover the waste, materials and energy that remain in use products at the end of the lifecycle	Channels of communication with costumers to retrieve products that they no longer use or that they want to renew	–
	Recovery and industrial recirculation of materials that consumers do not use any more	Build-up of waste minimised
		Incineration and landfill limited to a minimum
		Dissipative losses of valuable resources minimised
		Reuse of components
		Value of materials preserved in the economy through high-quality recycling

4.3. Methodology

The research questions posed in the study are answered based on the theoretical framework described in the previous section, and an analysis of the environmental statements of EMAS-registered businesses in the industrial sector in Catalonia (northeast Spain). The study presents an exploratory analysis of public environmental statements, or those verified by accredited third parties. To achieve this, the research was carried out in several stages.

Firstly, access was gained to the European Commission's EU EMAS Helpdesk register, and in June 2019, a list of 845 EMAS-verified centres in Spain was obtained. Of these, 233 pertain to businesses in Catalonia and 59 to the industrial sector. Of these, 31 are SMEs, and make up the study population (see Table 4).

Table 4. Description of the study population

Sector	Number EMAS Register
Industry and manufacturing	59
Services/Education/Health	27
Tourism	37
Retail/Logistics	16
Construction	16
Public administration	23
Waste management	38
Others	17
TOTAL Catalonia	**233**

The second step was to search for the statements directly on the company websites, or when they were not found directly, using the web search engine. In the search, the following criteria were taken into account: (1) most recent environmental statement and (2) Spanish and/or Catalan language and the key words: "Name of the company" + "EMAS statement/Environmental statement" and/or "EMAS verification number". A review process was then carried out to ensure that the documents met the above criteria and were accessible for Optical Character Recognition (OCR). In addition, in order to ensure the information was relevant, all documents were verified by an accredited verification body.

Thirdly, to determine what data should be collected from the statements and which ones would provide relevant information on circularity practices, the characteristics of the two models were used in way that was complementary: Fields of action and the EEA key characteristics (see Table 3). Based on the above, a list of 23 CE practices was obtained, grouped into 6 categories: Natural Resources (NR), Renewable Energy (RE), Raw Materials (RM), Reduce Emission (EM), Waste Management (WM) and Product Lifecycle (LC) and classified according to the fields of action proposed by Prieto-Sandoval et al. [20] (see Table 5).

Table 5. Elements of Fields of Action model and CE practices

Field of action	Elements	Code	CE Practices	Category
Take	Selection of biodegradable materials in different value chains	RM2	Replacement of materials with renewable ones	Raw Materials (RM)
		RM3	Selection of biodegradable materials	
	Selection of easy recirculated materials in different value chains	RM1	Improved raw materials use efficiency in production	
		RM4	Use of sustainable/renovable raw materials	
		RM5	Use of recycled/recirculated raw materials	
		RM6	Certification/evaluation of suppliers' environmental behavior	
	Environmental efficiency of production processes to reduce resources use	NR1	Improved water efficiency in production	Natural Resources (NR)
		NR2	Improved energy efficiency in production	
	Environmental efficiency of production processes to reduce emissions	EM1	Reduced emissions due to less extraction of raw material	Emissions (EM)
		EM2	Reduced emissions stemming from using clean energies	
		EM3	Reduced emissions by optimizing materials/machinery/processes	
	Sustainable energy sources for production	RE1	Use of renewable energy	Renewable Energy (RE)
Make	Environmental innovation in the design of sustainable products and services, in order to extend their lifecycles and facilitate recovery in the future.	LC1	Extended product lifetime	Product Lifecycle (LC)
		LC3	Eco-design	
		LC6	Product traceability	
	The recovery of raw materials and resources in the internal process of the company	WM1	Decreased no-hazardous waste generation concerning production	Waste Management (WM)
			Decreased hazardous waste generation concerning production	
		WM3	Waste recovery	
		WM4	By-products	
		WM5	Reintegrated waste into the internal production process	
Recover	Recovery and industrial recirculation of materials that consumers do not use any more	LC2	Reused/refurbished/remanufactured products	Product Lifecycle (LC)
		LC4	Easy components separation	
		LC5	Returning materials to the factory after use	

The data grid (Table S1) was designed, corroborated and validated by the researchers to establish whether the information was available in the statements. Both qualitative data on circularity practices mentioned (1) and no mentioned (0), and quantitative data (positive (1) or negative (0) performance variation) were gathered. Quantitative data compiled consumption of water, energy, raw materials and waste, which was related to both the production volume, as well as differences in comparison to the previous year (see Figure 1).

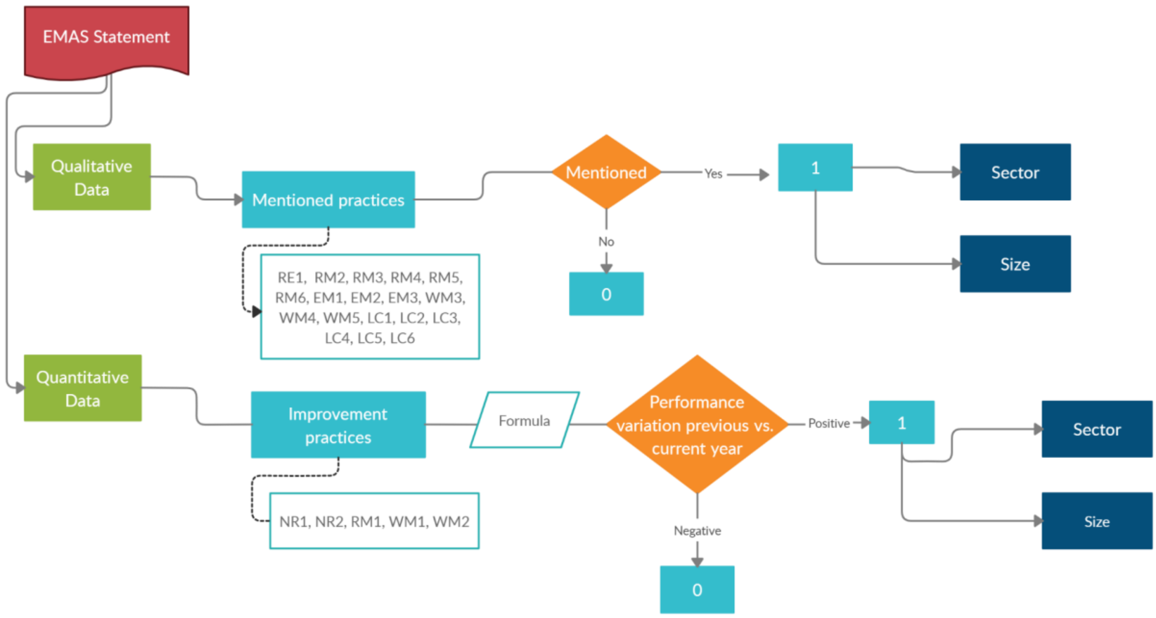

Figure 1. Data coding and classification process.

The fourth step involved searching for the data, then coding it using *Atlas.ti* software. All three researchers analysed and categorized all the information in the documents following the research model (see Table S1, Figures S1 and S2 in Supplementary Materials). The same protocol of action was followed and added the grid designed and agreed by all members of the group in order to ensure reliability and validity [104].

Finally, the data gathered independently was verified and discussed by the researchers in order to avoid errors before adding them to the grid with the final information chosen. The data was subsequently statistically processed using the SPSS v25 software.

4.4. Results

In accordance with the objectives of the study, the Research Questions are thus answered.

4.4.1. RQ1: Do Companies Include the CE Concept in Their Environmental Statements?

Of the 31 statements analysed, only 3 explicitly mentioned the term "Circular Economy". It should be noted that the time period of the statements studied is from 2016 to 2019, and the incursion of the term is relatively recent in the business world.

4.4.2. RQ2: What CE Activities or Practices do Companies Claim to Have Adopted? Are Some Activities more Commonly Adopted than Others?

Although the term is not explicitly mentioned in most of the statements, one of the aims of the study was to explore which circularity practices are mentioned in the environmental statements of EMAS-registered organisations in the industrial sector in Catalonia. A total of 23 practices were identified, which can be grouped into 6 categories (1) Natural Resources,

(2) Renewable Energies, (3) Raw Materials, (4) Emissions, (5) Waste Management, and (6) Product Lifecycle. Figure 2 shows the number of companies mentioning these practices in their environmental statements. We can conclude that the most commonly implemented practices belong to the fields of action Take and Make.

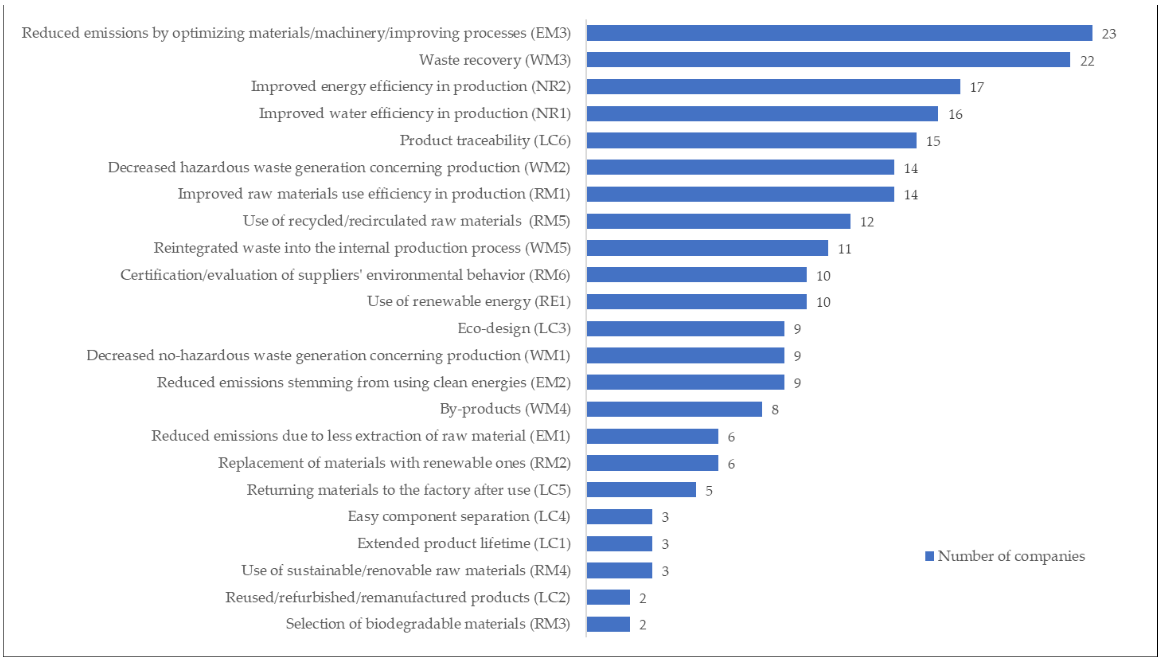

Figure 2. Circularity practices mentioned in the Eco-Management and Audit Scheme (EMAS) Environmental Statements.

To analyse the practices mentioned above, organisations were examined to see how they were distributed according to size and grouped by industrial sectors (Figure 3).

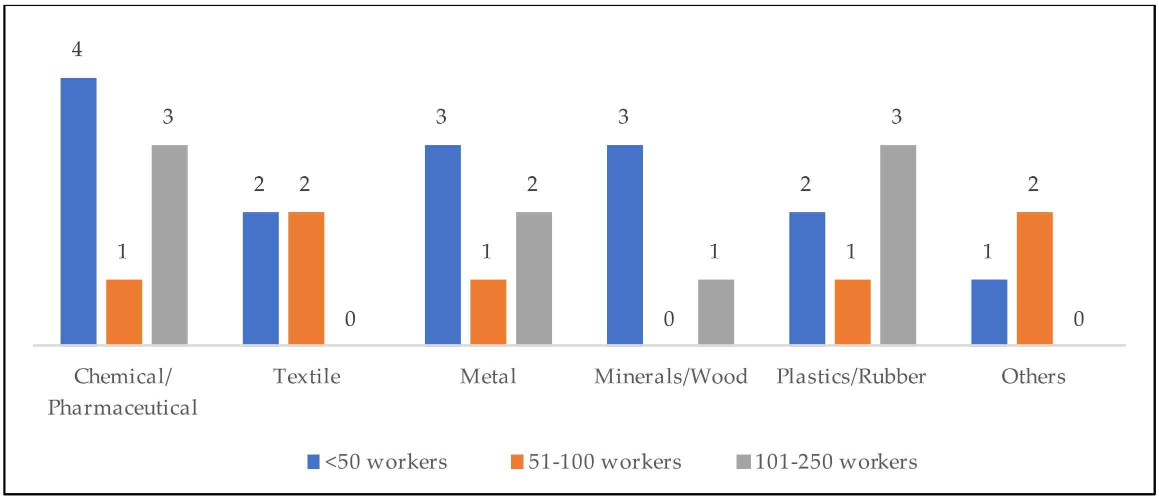

Figure 3. Population distribution by size and sector.

The practices were divided into two types: quantitative, which enabled the increase or decrease in yield to be calculated, and qualitative, which determined whether actions related to the practices were mentioned or not. For the quantitative practices, the following formula was used and adapted to either the consumption of natural resources or raw materials:

$$\textbf{Performance} = \frac{\frac{Water\ consumption\,\frac{m^3}{energy}(MWh)}{Annual\ production}\textbf{year} \;-\; \frac{Water\,\frac{consumption(m^3)}{energy(MWh)}}{Annual\ production}\textbf{previous year}}{\frac{Water\,\frac{consumption(m^3)}{energy(MWh)}}{Annual\ production}\textbf{previous year}}$$

and for waste reduction:

$$\textbf{Waste generated} = \frac{\frac{Hazardous\ and\ Non\ Hazardous\ waste}{Annual\ production}\textbf{year} \;-\; \frac{Hazardous\ and\ Non\ Hazardous\ waste}{Annual\ production}\textbf{previous year}}{\frac{Hazardous\ and\ Non\ Hazardous\ waste}{Annual\ production}\textbf{previous year}}$$

Table 6 shows the practices organisations have implemented corresponding to the size or industry sector group. In the performance practices (Improved water efficiency in production, Improved energy efficiency in production, Improved raw materials use efficiency in production) those with increased performance were counted.

Table 6. Contingency table. Distribution of practices by company size and sector groupings

CE Practice			Size			Sectors							
		CE practices by category	<50 workers	51 to 100 workers	101 to 250 workers	Chemical / Pharma	Textile	Metal	Minerals/Wood	Plastics/Rubber	Others	Total per practice	%
#	Code	*General distributión of practices by groupings*	*15*	*7*	*9*	*8*	*4*	*6*	*4*	*6*	*3*	-	-
		Natural resources category (NR)											
1	NR1	Improved water efficiency in production	8	3	5	4	1	4	2	4	1	16	52%
2	NR2	Improved energy efficiency in production	9	6	2	3	3	3	1	5	2	17	55%
		Renewable energy category (RE)											
3	RE1	Use of renewable energy	5	0	5	3	0	2	4	0	1	10	32%
		Raw materials category (RM)											
4	RM1	Improved raw materials use efficiency in production	7	2	5	5	1	2	1	4	1	14	45%
5	RM2	Replacement of materials with renewable ones	3	1	2	3	0	0	1	1	1	6	19%
6	RM3	Selection of biodegradable materials	0	1	1	1	0	0	0	0	1	2	6%
7	RM4	Use of sustainable/renovable raw materials	1	1	1	1	0	0	1	0	1	3	10%
8	RM5	Use of recycled/recirculated raw materials	6	1	5	3	1	1	2	5	0	12	39%
9	RM6	Certification/evaluation of suppliers' environmental behavior	4	1	5	1	1	1	2	4	1	10	32%
		Reduced emissions category (EM)											
10	EM1	Reduced emissions due to less extraction of raw material	3	1	2	1	0	1	2	2	0	6	19%
11	EM2	Reduced emissions stemming from using clean energies	5	1	3	3	0	0	4	1	1	9	29%
12	EM3	Reduced emissions by optimizing materials/machinery/improving processes	10	5	8	5	2	5	4	5	2	23	74%
		Waste management category (WM)											
13	WM1	Decreased no-hazardous waste generation concerning production	3	4	2	2	1	1	1	3	1	9	29%
14	WM2	Decreased hazardous waste generation concerning production	7	3	4	2	1	2	4	4	1	14	45%
15	WM3	Waste recovery	11	4	7	4	3	4	3	5	3	22	71%
16	WM4	By-products	5	1	2	0	2	1	3	2	0	8	26%
17	WM5	Reintegrated waste into the internal production process	5	2	4	3	3	1	3	1	0	11	35%
		Product lifecycle category (LC)											
18	LC1	Extended product lifetime	2	0	1	0	1	1	1	0	0	3	10%
19	LC2	Reused/refurbished/remanufactured products	2	0	0	1	0	0	1	0	0	2	6%
20	LC3	Eco-design	4	0	5	1	1	1	1	4	1	9	29%
21	LC4	Easy components separation	1	0	2	0	0	0	1	2	0	3	10%
22	LC5	Returning materials to the factory after use	2	1	2	0	1	1	1	1	1	5	16%
23	LC6	Product traceability	8	3	4	2	1	2	4	4	2	15	48%

It was noted that some practices were mentioned more frequently in the statements; for example, reducing emissions by optimizing materials, machinery or improving processes (74%). Within this practice, it is worth highlighting that the main practice mentioned by the majority of organisations was that renewing equipment or machinery enables them to reduce the consumption of natural resources and/or raw materials, which in turn reduces emissions. The second most frequently mentioned practice is waste recovery (72%), most of which was carried out through an authorized manager. No information was found in the statements on the behaviour of organisations in relation to limits of waste in landfill or incineration, and confusion was detected when using the terms recovery, waste treatment and by-products.

All the statements were checked for mention of practices employed to improve water and energy consumption performance, and calculations were made to determine differences in performance compared to the previous year. Of the 31 organisations analysed, findings showed that 52 per cent achieved improvements in water use performance and 55 per cent in energy use performance.

In the Product Lifecycle category, fewer CE-related actions were found, with the exception of product traceability (48%). Organisations generally mentioned that they take the product lifecycle into account, but there were no details available regarding how they could monitor or track products, parts or components once they had left their facilities or production plants.

The contingency table (see Table 6), in which binary data compare 3 or more independent groups, was carried out in order to check whether the participation of the analysed companies in CE practices according to their sector and size.

Significant associations between circularity practices in size grouping were observed in the following cases:

- Improved energy efficiency in production: while companies with 51–100 workers showed increased energy efficiency (6 out of 7), only 1 out of 4 of the companies with 101–250 workers showed a decrease.
- Renewable energy use: companies with <50 workers and those with 101–250 workers mention renewable energy (5 out of 15, and 5 out of 8, respectively). Companies with 51–100 workers do not report using renewable energy (0 out of 7).
- Eco-design: companies with <50 workers and those with 101–250 workers mention eco-design in their statements (4 out of 15, and 5 out of 8, respectively). Companies with 51–100 workers do not report any eco-design actions (0 out of 7).

By sector, significant differences were found in the following cases:

- Renewable energy use: while the total of the companies in the Minerals/Wood group (4 out of 4) reported using renewable energies, the Textile and Other industries groups do not mention using renewable energies (0 out of 4 and 0 out of 6, respectively).
- Reduction in emissions stemming from using clean energies: The Minerals/Wood group mentions a reduced emissions from clean energy use (4 out of 4); the Textile and Metal groups do not mention any actions taken regarding clean energies (0 out of 4 and 0 out of 6).

Finally, in order to analyse the relationship between circularity practices, the Phi correlation coefficient test was carried out as these are nominal dichotomous variables [105]. The correlation matrix (Table S2) indicates that practices are related, both within the same category (Raw Materials, Emission Reduction, Waste Management and Product Lifecycle) and between categories. The coloured cells are significant relationships.

Table 7 summarizes the practices most frequently related to CE and Table 8 shows the cases in which correlations were found between practices in various categories.

Table 7. Relationship between practices considered drivers of change towards a CE

Relationship between Practices Considered Drivers	
LC3—Eco-design	EM3—Reduced emissions by optimizing materials/machinery/ improving processes
	RM1—Improved raw materials use efficiency in production
	LC1—Extended product lifetime
	LC4—Easy components separation
	LC5—Returning materials to the factory after use
LC5—Returning materials to the factory after use	RM4—Use of sustainable/renewable raw materials
	RM5—Use of recycled and/or recirculated raw materials
	LC1—Extended product lifetime
	LC3—Eco-design
	LC4—Easy components separation
RM5—Use of recycled and/or recirculated raw materials	EM1—Reduced emissions due to less extraction of raw material
	WM5—Reintegrated waste into the internal production process
	LC1—Extended product lifetime
	LC5—Returning materials to the factory after use
LC1—Extended product lifetime	RM5—Use of recycled and/or recirculated raw materials
	WM5—Reintegrated waste into the internal production process
	LC3—Eco-design
	LC5—Returning materials to the factory after use

The aim of colouring the practices is for better understanding. Eco-design coloured in green (5 related practices), Material return coloured in blue (5 related practices), Use of recycled and/or recirculated raw materials coloured in yellow (4 related practices) and Product life cycle extension strategies coloured in grey (4 related practices).

Table 8. Relationship between CE practices with significant correlation ($p < 0.05$)

No.	Practice *a*	Practice *b*	Phi coefficient	Correlation
1	RM3 - Selection of biodegradable materials	RM4 - Use of sustainable/renovable raw materials	0,802	high
2	LC1 - Extended product lifetime	LC5 - Returning materials to the factory after use	0,745	high
3	LC1 - Extended product lifetime	LC3 - Eco-design	0,509	moderate
4	LC3 - Eco-design	LC4 - Easy components separation	0,509	moderate
5	LC3 - Eco-design	LC5 - Returning materials to the factory after use	0,488	moderate
6	WM2 - Decreased hazardous waste generation concerning production	WM4 - By-products	0,484	moderate
7	WM4 - By-products	WM5 - Reintegrated waste into the internal production process	0,48	moderate
8	RE1 - Use of renewable energy	EM2 - Reduced emissions stemming from using clean energies	0,463	moderate
9	LC4 - Easy components separation	LC5 - Returning materials to the factory after use	0,447	moderate
10	RM4 - Use of sustainable/renovable raw materials	LC5 - Returning materials to the factory after use	0,447	moderate
11	RM5 - Use of recycled/recirculated raw materials	EM1 - Reduced emissions due to less extraction of raw material	0,442	moderate
12	WM5 - Reintegrated waste into the internal production process	LC1 - Extended product lifetime	0,438	moderate
13	RM5 - Use of recycled/recirculated raw materials	LC1 - Extended product lifetime	0,408	moderate
14	RM1 - Improved raw materials use efficiency in production	LC3 - Eco-design	0,408	moderate
15	EM2 - Reduced emissions stemming from using clean energies	LC2 - Reused/refurbished/ remanufactured products	0,408	moderate
16	WM1 - Decreased no-hazardous waste generation concerning production	WM2 - Decreased hazardous waste generation concerning production	0,408	moderate
17	RE1 - Use of renewable energy	EM3 - Reduced emissions by optimizing materials/machinery /improving processes	0,390	low
18	RM2 - Replacement of materials with renewable ones	EM1 - Reduced emissions due to less extraction of raw material	0,375	low
19	RM5 - Use of recycled/recirculated raw materials	WM5 - Reintegrated waste into the internal production process	0,367	low

20	RM5 - Use of recycled/recirculated raw materials	LC5 - Returning materials to the factory after use	0,365	low
21	WM3 - Waste recovery	WM4 - By-products	0,364	low
22	EM2 - Reduced emissions stemming from using clean energies	EM3 - Reduced emissions by optimizing materials/machinery /improving processes	0,361	low
23	EM3 - Reduced emissions by optimizing materials/machinery /improving processes	LC3 - Eco-design	0,361	low
24	NR2 - Improved energy efficiency in production	RE1 - Use of renewable energy	-0,381	low (negative)

Correlations between practices of the same category coloured in yellow; Correlations between practices of different categories coloured in green

Within the group of businesses analysed, 23 directly positive correlations were found: 2 high (with correlation strength between 1 and 0.7), 14 moderate (between 0.69 and 0.4), 7 low (between 0.39 and 0.10) and 1 low inverse correlation (<0) was also found. The practices showing the highest correlation were using biodegradable raw materials and raw materials of sustainable and/or biodegradable origin ($r\phi$ = 0.802), followed by extending product life cycle and returning materials to the factory after use ($r\phi$ = 0.745). In contrast, practices employed to improve energy efficiency and use renewable energies showed a low negative correlation ($r\phi$ = −0381).

4.4.3. RQ3: How Are CE Practices Reported and Quantified in Environmental Statements? How Are These Practices Reported to Stakeholders?

As mentioned above, previous studies on implementing circularity practices at micro level, especially in SMEs, were taken as a reference for this study. From there, the list of search criteria for CE practices within the statements was established (see Table S1). Although the majority of the statements are structured in accordance with the indications of the EMAS regulation, a wide disparity was found in the way the results were presented, especially with regard to the consumption of natural resources, raw materials, particularly the production indicator (m^3, tones, physical units or by number of workers) which indicate whether yields show an improvement or a decrease.

The statements also differed widely regarding the number of workers involved, the length of the documents and the way in which each organisation presents the information. Standardising the information required by EMAS could help stakeholders access the data in a clearer and simpler way, as well as enabling comparative studies between companies to be carried out.

4.4.4 RQ4: Does a Relationship Exist between Circularity Practices and Economic Performance?

To analyse the economic performance of the companies in the study, Turnover, Net Profit and Economic Profitability variables of the SABI database were examined (see Table S1). Finally, we chose to only focus our analysis on Turnover due to the differences in the types of organisations in both size and sector. No significant correlation was found which could determine a relationship between incorporating circularity practices and economic performance.

4.4.5. RQ5: What Information Should Be Included in Environmental Statements in the Future to Help Evaluate the Application of Circularity Practices in EMAS-Registered Companies?

With a view to strengthening the statements beyond being just a tool for providing information on the consumption of natural resources, raw materials and environmental behaviour in generating waste and emissions, it would also be useful to know if the organisation is registered with an industrial cluster of some kind in order to reuse by-products, or for companies to provide more precise information on changing to renewable energies and the percentage of use with respect to total consumption, and whether this is self-generated.

Of the six categories analysed (see Table 6), Product Life Cycle is the least covered or addressed, but it offers the most opportunities for entering into CE and close the cycle of processes and products.

4.5. Discussion and Conclusions

Based on the analytical framework and models proposed at the micro level, this study has identified 23 circularity practices that are currently being adopted by SME companies with EMAS regulation in the industrial sector in Catalonia. Based on the model proposed by Prieto-Sandoval et al. [20], we can conclude that of the 5 fields of action needed to make the transition to the CE model (Take, Make, Use, Distribution and Recover), the majority of the practices implemented only mainly refer to Take and to a lesser extent to Make and Recover. The results of our study are in line with those obtained in Spain by Ormazábal et al., 2016 [21] (Take and Recover); Ormázabal et al., 2018 [47]] (Take),; and Aranda-Usón et al., 2020 [18] (Take and Recover). At the European level, in Portugal, Fonseca et al., 2018 [13] highlight Take and Recover, as does Mura et al., 2020 [52] in Italy. Janik and Szafraniec, 2019 [84], describe practices associated with Take in Poland. Therefore, it can be concluded that most of the studies detected coincide in highlighting circular practices mainly in the fields of Take and Recover.

EMAS companies have made headway in measuring and quantifying consumption of natural resources and emissions and waste generated. However, it is clear that the EMAS model has not contributed to standardising how information is presented in statements nor to using general indicators to facilitate comparisons between companies. Several statements showed that companies report their environmental impacts without making reference to their annual production volumes. Results also showed that the units used to give the data differ from one company to another, making it very difficult to compare the progression of implementing circularity actions between companies, as pointed out by Janik and Szafraniek [84]. As mentioned by Aranda et al. [18], findings demonstrate that standardized metrics need to be implemented in order to measure the environmental impact of CE activities within companies.

To date, no consensus has been reached in the literature as to which indicators are the most suitable for measuring circularity and can be applied by SMEs. Therefore, the authors of this study propose taking the key characteristics of CE into consideration according to the fields of action. The implementation of a production model based on CE means much more than reducing waste through recycling. It also requires reducing the consumption of raw materials, designing environmentally friendly products that can be easily recovered and reused, lengthening product lifetimes through proper maintenance, using recyclable materials in products and taking actions to recover raw materials from waste streams [1].

In relation to groups by size and sector, the results show that organisations with <50 and 101–250 workers, and those in the Minerals/Wood sector are more concerned about practices related to using renewable energies and the reduction of emissions. These same groups of companies, by size, also correspond to those that reported practices aimed at product eco-design. Similarly, the correlation matrix clearly demonstrates that using renewable energies is linked to emission reduction practices. Future studies could analyse this in greater depth by looking at different years and standardizing production indicators for CE practices among companies.

Eco-design was one of the practices with the highest correlation and is associated with Returning materials to the factory after use, Extending product lifecycle, Reintegrating waste into the internal production process and Using recycled and recirculated raw materials (see Table 9). This analysis enables associations between practices to be detected; however, future research could investigate whether causality between CE practices exists and what factors motivate internalizing environmental discourse within companies [78].

Other practices such as using biodegradable raw materials are closely linked to raw materials of sustainable origin or from renewable sources. Reusing/reconditioning/remanufacturing products and parts is beginning to appear in statements, although in an incipient way and may require emphasising the areas of Distribute and Use to facilitate its implementation.

Although waste recovery occurs in 71% of the companies researched, it is only linked to by-products. This corroborates the study by Daddi et al. [106], which points out the importance of encouraging the development of eco-industrial parks and strengthening business associations, clusters, and all kinds of groups and networks in order to work at a meso level and move towards an economy based on collaborative networks. The fact that no practices have been detected in the areas of Distribute and Use indicates that CE practices need to be extended beyond the internal level in EMAS-registered companies in Catalonia's industrial sector. It is essential to understand that the CE model does not affect individual companies but rather refers to the interconnection of the business fabric as a whole [101,107], as well as the rest of stakeholders in order to successfully introduce the concept of CE on a large scale [10]. A key factor could be to facilitate communication between the various stakeholders (organisations, customers, users, administration). However, for this to occur, more efficient information and communication tools need to be developed that will enable companies and organisations to continue improving the practices implemented, as well as making inroads into others that will enhance the circular model.

Finally, along the lines of Aranda-Usón et al. [18], this study has also failed to detect any significant correlation that could determine any relationship between the incorporating circularity practices and a company's economic performance.

This study is limited to analysing CE practices in industrial sector SMEs with EMAS in Catalonia. Several proposals are put forward for future research: (a) widen the study to include the trade and service sectors, (b) extend the study to companies with other types of EMS already in place such as ISO 14001, (c) replicate similar research in other regions or countries and (d) carry out studies based on developing surveys or questionnaires enabling an in-depth analysis of the extent to which these CE practices are adopted by businesses.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figure S1: Example Codification 1 with Atlas.ti. Source: screenshot of document encoding in Atlas.ti (Version 8.4.24.9), Figure S2: Example Codification 2 with Atlas.ti. Source: screenshot of document encoding in Atlas.ti (Version 8.4.24.9) Table S1: Data collection grid; Table S2: Phi coefficient correlation matrix of circularity practices.

References

1. Ellen MacArthur Fundation. TOWARDS THE CIRCULAR ECONOMY. *Econ. Bus. Ration. Accel. Transition* 2013, 1.

2. Mitchell P. Economic Growth Potential of More Circular Economies. WRAP (Waste & Resources Action Programme); 2015. Available online: https://www.researchgate.net/publication/284187423_Economic_growth_potential_of_more_circular_economies (accessed on 15 October 2020).

3. European Environment Agengy. Circular economy in Europe—Developing the Knowledge Base—European Environment Agency. Available online: https://www.eea.europa.eu/publications/circular-economy-in-europe (accessed on 27 July 2020); Published 2016.

4. Veleva, V.R.; Bodkin, G. Corporate-entrepreneur collaborations to advance a circular economy. *J. Clean. Prod.* **2018**, *188*, 20–37, doi:10.1016/j.jclepro.2018.03.196

5. Franco, M.A. Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *J. Clean. Prod.* **2017**, *168*, 833–845, doi:10.1016/j.jclepro.2017.09.056.

6. Lewandowski, M. Designing the Business Models for Circular Economy—Towards the Conceptual Framework. *Sustainability* **2016**, *8*, 43, doi:10.3390/su8010043.

7. Pieroni, M.P.; McAloone, T.C.; Pigosso, D.C. Business model innovation for circular economy and sustainability: A review of approaches. *J. Clean. Prod.* **2019**, *215*, 198–216, doi:10.1016/j.jclepro.2019.01.036.

8. Garcés-Ayerbe, C.; Rivera-Torres, P.; Suárez-Perales, I.; La Hiz, D.I.L.-D. Is It Possible to Change from a Linear to a Circular Economy? An Overview of Opportunities and Barriers for European Small and Medium-Sized Enterprise Companies. *Int. J. Environ. Res. Public Heal.* **2019**, *16*, 851, doi:10.3390/ijerph16050851

9. Katz-Gerro, T.; Sintas, J.L. Mapping circular economy activities in the European Union: Patterns of implementation and their correlates in small and medium-sized enterprises. *Bus. Strat. Environ.* **2018**, *28*, doi:10.1002/bse.2259.

10. Lieder, M.; Rashid, A. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *J. Clean. Prod.* **2016**, *115*, 36–51, doi:10.1016/j.jclepro.2015.12.042.

11. European Comission. Moving towards a Circular Economy with EMAS. *Luxemburg* **2017**, doi:10.2779/463312

12. Marrucci, L.; Daddi, T.; Iraldo, F. The integration of circular economy with sustainable consumption and production tools: Systematic review and future research agenda. *J. Clean. Prod.* **2019**, *240*, 118268, doi:10.1016/j.jclepro.2019.118268.

13. Fonseca, L.M.; Domingues, J.P.; Pereira, M.T.; Martins, F.; Zimon, D. Assessment of Circular Economy within Portuguese Organizations. *Sustainability* **2018**, *10*, 2521, doi:10.3390/su10072521.

14. Ormazabal, M.; Sarriegi, J.M.; Barkemeyer, R.; Viles, E.; McAnulla, F. Evolutionary Pathways of Environmental Management in UK Companies. *Corp. Soc. Responsib. Environ. Manag.* **2013**, *22*, 169–181, doi:10.1002/csr.1341.

15. Parker, C.M.; Redmond, J.; Simpson, M. A Review of Interventions to Encourage SMEs to Make Environmental Improvements. *Environ. Plan. C: Gov. Policy* **2009**, *27*, 279–301, doi:10.1068/c0859b.

16. EMAS Register. Register of EMAS Firms. Available online: https://webgate.ec.europa.eu/emas2/public/registration/list (accessed on 15 July 2019.); Published 2020.

17. Del Río, P.; Carrillo-Hermosilla, J.; Könnölä, T.; Bleda, M. Resources, capabilities and competences for eco-innovation. *Technol. Econ. Dev. Econ.* **2015**, *22*, 274–292, doi:10.3846/20294913.2015.1070301.

18. Aranda-Usón, A.; Portillo-Tarragona, P.; Scarpellini, S.; Llena-Macarulla, F. The progressive adoption of a circular economy by businesses for cleaner production: An approach from a regional study in Spain. *J. Clean. Prod.* **2020**, *247*, doi:10.1016/j.jclepro.2019.119648.

19. European Comission. Towards a Circular Economy: A Zero Waste Programme for Europe. *Brussels* **2014**. Available online: http://ec.europa.eu/environment/resource_efficiency/re_platform/index_en.htm (accessed on 5 September 2020).

20. Prieto-Sandoval, V.; Ormazabal, M.; Jaca, C.; Viles, E. Key elements in assessing circular economy implementation in small and medium-sized enterprises. *Bus. Strat. Environ.* **2018**, *27*, 1525–1534, doi:10.1002/bse.2210.

21. OOrmazabal, M.; Prieto-Sandoval, V.; Jaca, C.; Santos, J. An overview of the circular economy among SMEs in the Basque country: A multiple case study. *J. Ind. Eng. Manag.* **2016**, *9*, 1047–1058, doi:10.3926/jiem.2065.

22. Portillo P, Estudios C. *Nivel de Implantación de la Economía Circular en Aragón*; 2017.

23. Aranda-Usón, A.; Portillo-Tarragona, P.; Marín-Vinuesa, L.M.; Scarpellini, S. Financial Resources for the Circular Economy: A Perspective from Businesses. *Sustainability* **2019**, *11*, 888, doi:10.3390/su11030888.

24. European Comission. Closing the Loop - An EU Action Plan for the Circular Economy. *Brussels* **2015**. Available online: https://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF (accessed on 5 September 2020).

25. Manninen, K.; Koskela, S.; Antikainen, R.; Bocken, N.; Dahlbo, H.; Aminoff, A. Do circular economy business models capture intended environmental value propositions? *J. Clean. Prod.* **2018**, *171*, 413–422, doi:10.1016/j.jclepro.2017.10.003.

26. Witjes, S.; Lozano, R. Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resour. Conserv. Recycl.* **2016**, *112*, 37–44, doi:10.1016/j.resconrec.2016.04.015.

27. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.; Hultink, E.J. The Circular Economy–A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768, doi:10.1016/j.jclepro.2016.12.048.

28. Walls, J.L.; Paquin, R.L. Organizational Perspectives of Industrial Symbiosis. *Organ. Environ.* **2015**, *28*, 32–53, doi:10.1177/1086026615575333.

29. Zeng, H.; Chen, X.; Xiao, X.; Zhou, Z. Institutional pressures, sustainable supply chain management, and circular economy capability: Empirical evidence from Chinese eco-industrial park firms. *J. Clean. Prod.* **2017**, *155*, 54–65, doi:10.1016/j.jclepro.2016.10.093.

30. Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232, doi:10.1016/j.resconrec.2017.09.005.

31. Prieto-Sandoval, V.; Jaca, C.; Ormazabal, M. Towards a consensus on the circular economy. *J. Clean. Prod.* **2018**, *179*, 605–615, doi:10.1016/j.jclepro.2017.12.224.

32. Murray, A.; Skene, K.; Haynes, K. The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *J. Bus. Ethic.* **2015**, *140*, 369–380, doi:10.1007/s10551-015-2693-2.

33. Ellen Macarthur Foundation. Growth within: A circular economy vision for a competitive Europe. *Ellen MacArthur Found* **2015**, *100*.

34. Ghisellini, P.; Cialani, C.; Ulgiati, S. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* **2016**, *114*, 11–32, doi:10.1016/j.jclepro.2015.09.007.

35. Yuan, Z.; Bi, J.; Moriguichi, Y. The Circular Economy: A New Development Strategy in China. *J. Ind. Ecol.* **2008**, *10*, 4–8, doi:10.1162/108819806775545321.

36. Li, H.; Bao, W.; Xiu, C.; Zhang, Y.; Xu, H. Energy conservation and circular economy in China's process industries. *Energy* **2010**, *35*, 4273–4281, doi:10.1016/j.energy.2009.04.021.

37. Andersen, M.S. An introductory note on the environmental economics of the circular economy. *Sustain. Sci.* **2006**, *2*, 133–140, doi:10.1007/s11625-006-0013-6.

38. Kama, K. Circling the economy: resource-making and marketization in EU electronic waste policy. *Area* **2014**, *47*, 16–23, doi:10.1111/area.12143.

39. Zhijun, F.; Nailing, Y. Putting a circular economy into practice in China. *Sustain. Sci.* **2007**, *2*, 95–101, doi:10.1007/s11625-006-0018-1.

40. Ehrenfeld, J.; Gertler, N. Industrial Ecology in Practice: The Evolution of Interdependence at Kalundborg. *J. Ind. Ecol.* **1997**, *1*, 67–79, doi:10.1162/jiec.1997.1.1.67.

41. Jacobsen, N.B. Industrial Symbiosis in Kalundborg, Denmark: A Quantitative Assessment of Economic and Environmental Aspects. *J. Ind. Ecol.* **2008**, *10*, 239–255, doi:10.1162/108819806775545411.

42. Liu, Q.; Li, H.-M.; Zuo, X.-L.; Zhang, F.-F.; Wang, L. A survey and analysis on public awareness and performance for promoting circular economy in China: A case study from Tianjin. *J. Clean. Prod.* **2009**, *17*, 265–270, doi:10.1016/j.jclepro.2008.06.003.

43. Morlet, A.; Blériot, J.; Opsomer, R.; et al. Intelligent Assets: Unlocking the Circular Economy Potential, by the Ellen MacArthur Foundation and World Economic Forum as Part of Project MainStream 2016. Available online: https://www.ellenmacarthurfoundation.org/publications/intelligent-assets (accessed on 5 September 2020).

44. Haas, W.; Krausmann, F.; Wiedenhofer, D.; Heinz, M. How Circular is the Global Economy? An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005. *J. Ind. Ecol.* **2015**, *19*, 765–777, doi:10.1111/jiec.12244.

45. Mathews, J.A.; Tan, H. Progress Toward a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative. *J. Ind. Ecol.* **2011**, *15*, 435–457, doi:10.1111/j.1530-9290.2011.00332.x.

46. Saidani, M.; Yannou, B.; Leroy, Y.; Cluzel, F. How to Assess Product Performance in the Circular Economy? Proposed Requirements for the Design of a Circularity Measurement Framework. *Recycling* **2017**, *2*, 6, doi:10.3390/recycling2010006.

47. Ormazabal, M.; Prieto-Sandoval, V.; Puga-Leal, R.; Jaca, C. Circular Economy in Spanish SMEs: Challenges and opportunities. *J. Clean. Prod.* **2018**, *185*, 157–167, doi:10.1016/j.jclepro.2018.03.031.

48. Elkington, J. *The Triple Bottom Line. Does it All Add Up?* Henriques, A., Richardson, J., Eds.; Routledge: 2001; pp. 1–16.

49. Ministerio Industria. Cifras PYME. Publicaciones Ministerio de Industria. Available online: http://www.ipyme.org/Publicaciones/cifraspyme-enero2020.pdf. Published 2020 (accessed on 15 March 2020).

50. Geng, Y.; Doberstein, B. Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'. *Int. J. Sustain. Dev. World Ecol.* **2008**, *15*, 231–239, doi:10.3843/susdev.15.3:6.

51. Rizos, V.; Behrens, A.; Van Der Gaast, W.; Hofman, E.; Ioannou, A.; Kafyeke, T.; Flamos, A.; Rinaldi, R.; Papadelis, S.; Hirschnitz-Garbers, M.; et al. Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers. *Sustainability* **2016**, *8*, 1212, doi:10.3390/su8111212.

52. Mura, M.; Longo, M.; Zanni, S. Circular economy in Italian SMEs: A multi-method study. *J. Clean. Prod.* **2020**, *245*, 118821, doi:10.1016/j.jclepro.2019.118821.

53. Agyemang, M.; Kusi-Sarpong, S.; Khan, S.A.; Mani, V.; Rehman, S.T.; Kusi-Sarpong, H. Drivers and barriers to circular economy implementation. *Manag. Decis.* **2019**, *57*, 971–994, doi:10.1108/md-11-2018-1178.

54. Shi, H.; Peng, S.; Liu, Y.; Zhong, P. Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. *J. Clean. Prod.* **2008**, *16*, 842–852, doi:10.1016/j.jclepro.2007.05.002.

55. Bassi, F.; Dias, J.G. The use of circular economy practices in SMEs across the EU. *Resour. Conserv. Recycl.* **2019**, *146*, 523–533, doi:10.1016/j.resconrec.2019.03.019.

56. Accenture Strategy. Insights Circular Advantatges.; 2015. Available online: https://www.accenture.com/es-es/insight-circular-advantage-innovative-business-models-value-growth. (accessed on 15 October 2020).

57. Thorley, J.; Garza-Reyes, J.A.; Anosike, A. The circular economy impact on small to medium enterprises. *Waste Manag. Environ. IX* **2018**, *231*, 257–267, doi:10.2495/wm180241.

58. Testa, F.; Heras-Saizarbitoria, I.; Daddi, T.; Boiral, O.; Iraldo, F. Public regulatory relief and the adoption of environmental management systems: A European survey. *J. Environ. Plan. Manag.* **2016**, *59*, 2231–2250, doi:10.1080/09640568.2016.1139491.

59. Moktadir, A.; Rahman, T.; Rahman, H.; Ali, S.M.; Paul, S.K. Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. *J. Clean. Prod.* **2018**, *174*, 1366–1380, doi:10.1016/j.jclepro.2017.11.063.

60. Gharfalkar, M. (Mangesh); Court, R. (Richard); Campbell, C. (Callum); Ali, Z. (Zulfiqur); Hillier, G. (Graham) Analysis of waste hierarchy in the European waste directive 2008/98/EC. *Waste Manag.* **2015**, *39*, 305–313, doi:10.1016/j.wasman.2015.02.007.

61. Fletcher, C.A.; Hooper, P.D.; Dunk, R.M. Unintended consequences of secondary legislation: A case study of the UK landfill tax (qualifying fines) order 2015. *Resour. Conserv. Recycl.* **2018**, *138*, 160–171, doi:10.1016/j.resconrec.2018.07.011.

62. Despeisse, M.; Kishita, Y.; Nakano, M.; Barwood, M. Towards a Circular Economy for End-of-Life Vehicles: A Comparative Study UK–Japan. *Procedia CIRP* **2015**, *29*, 668–673, doi:10.1016/j.procir.2015.02.122.

63. Ghisellini, P.; Ji, X.; Liu, G.; Ulgiati, S. Evaluating the transition towards cleaner production in the construction and demolition sector of China: A review. *J. Clean. Prod.* **2018**, *195*, 418–434, doi:10.1016/j.jclepro.2018.05.084.

64. Hu, Y.; He, X.; Poustie, M. Can Legislation Promote a Circular Economy? A Material Flow-Based Evaluation of the Circular Degree of the Chinese Economy. *Sustainability* **2018**, *10*, 990, doi:10.3390/su10040990.

65. Zink, T.; Geyer, R. Circular Economy Rebound. *J. Ind. Ecol.* **2017**, *21*, 593–602, doi:10.1111/jiec.12545.

66. Fischer, A.; Pascucci, S. Institutional incentives in circular economy transition: The case of material use in the Dutch textile industry. *J. Clean. Prod.* **2017**, *155*, 17–32, doi:10.1016/j.jclepro.2016.12.038.

67. Liu, Y.S.; Yang, J.H. A longitudinal analysis of corporate greenhouse gas disclosure strategy.*Corp. Gov. Int. J. Bus. Soc.* **2018**, *18*, 317–330, doi:10.1108/cg-11-2016-0213.

68. Lacy, P.; Rutqvist, J. The Sharing Platform Business Model: Sweating Idle Assets. *Waste Wealth* **2015**, *2015*, 84–98, doi:10.1057/9781137530707_7.

69. Daddi, T.; Iraldo, F.; Testa, F. *Environmental Certification for Organisations and Products: Management Approaches and Operational Tools*; Taylor and Francis Inc.: 2015, doi:10.4324/9781315768182

70. Chiarini, A. Setting Strategies outside a Typical Environmental Perspective Using ISO 14001 Certification. *Bus. Strat. Environ.* **2017**, *26*, 844–854, doi:10.1002/bse.1969.

71. Matuszak-Flejszman, A.; Szyszka, B.; Johannsdottir, L. Effectiveness of EMAS: A case study of Polish organisations registered under EMAS. *Environ. Impact Assess. Rev.* **2019**, *74*, 86–94, doi:10.1016/j.eiar.2018.09.005.

72. Boiral, O.; Guillaumie, L.; Heras-Saizarbitoria, I.; Tene, C.V.T. Adoption and Outcomes of ISO 14001: A Systematic Review. *Int. J. Manag. Rev.* **2017**, *20*, doi:10.1111/ijmr.12139.

73. Heras-Saizarbitoria, I.; Arana, G.; Boiral, O. Outcomes of Environmental Management Systems: the Role of Motivations and Firms' Characteristics. *Bus. Strat. Environ.* **2015**, *25*, 545–559, doi:10.1002/bse.1884.

74. Daddi, T.; Magistrelli, M.; Frey, M.; Iraldo, F. Do environmental management systems improve environmental performance? Empirical evidence from Italian companies. *Environ. Dev. Sustain.* **2011**, *13*, 845–862, doi:10.1007/s10668-011-9294-8.

75. Daddi, T.; Testa, F.; Frey, M.; Iraldo, F. Exploring the link between institutional pressures and environmental management systems effectiveness: An empirical study. *J. Environ. Manag.* **2016**, *183*, 647–656, doi:10.1016/j.jenvman.2016.09.025.

76. Iraldo, F.; Testa, F.; Frey, M. Is an environmental management system able to influence environmental and competitive performance? The case of the eco-management and audit scheme (EMAS) in the European Union. *J. Clean. Prod.* **2009**, *17*, 1444–1452, doi:10.1016/j.jclepro.2009.05.013.

77. Merli, R.; Preziosi, M. The EMAS impasse: Factors influencing Italian organizations to withdraw or renew the registration. *J. Clean. Prod.* **2018**, *172*, 4532–4543, doi:10.1016/j.jclepro.2017.11.031.

78. Testa, F.; Boiral, O.; Iraldo, F. Internalization of Environmental Practices and Institutional Complexity: Can Stakeholders Pressures Encourage Greenwashing? *J. Bus. Ethic.* **2015**, *147*, 287–307, doi:10.1007/s10551-015-2960-2.

79. Bracke, R.; Verbeke, T.; Dejonckheere, V. What Determines the Decision to Implement EMAS? A European Firm Level Study. *Environ. Resour. Econ.* **2008**, *41*, 499–518, doi:10.1007/s10640-008-9207-y.

80. European Comission. The Revised Annexes of the EMAS Regulation; 2017. Available online: http://ec.europa.eu/environment/emas/pdf/factsheets/EMAS_revised_annexes.pdf (accessed on).

81. Evans, L.; Nuttall, C.; Gandy, S.; et al. *Project to Support the Evaluation of the Implementation of the EU Ecolabel Regulation*; 2015, doi:10.2779/358489

82. Prieto-Sandoval, V.; Alfaro, J.A.; Mejía-Villa, A.; Ormazabal, M. ECO-labels as a multidimensional research topic: Trends and opportunities. *J. Clean. Prod.* **2016**, *135*, 806–818, doi:10.1016/j.jclepro.2016.06.167.

83. AENOR. EMAS: Se Actualizan Los Requisitos. Available online: https://revista.aenor.com/346/emas-se-actualizan-los-requisitos.html. (accessed on 10 June 2020); Published March 2019.

84. Janik, A.; Szafraniec, M. Circular economy performance of EMAS organizations in Poland based on an analysis of environmental statements. *Multidiscip. Asp. Prod. Eng.* **2019**, *2*, 536–547, doi:10.2478/mape-2019-0054.

85. Rashid, A.; Asif, F.M.; Krajnik, P.; Nicolescu, C.M. Resource Conservative Manufacturing: An essential change in business and technology paradigm for sustainable manufacturing. *J. Clean. Prod.* **2013**, *57*, 166–177, doi:10.1016/j.jclepro.2013.06.012.

86. Gusmerotti, N.M.; Testa, F.; Corsini, F.; Pretner, G.; Iraldo, F. Drivers and approaches to the circular economy in manufacturing firms. *J. Clean. Prod.* **2019**, *230*, 314–327, doi:10.1016/j.jclepro.2019.05.044.

87. Kristensen, H.S.; Mosgaard, M.A. A review of micro level indicators for a circular economy – moving away from the three dimensions of sustainability? *J. Clean. Prod.* **2020**, *243*, 118531, doi:10.1016/j.jclepro.2019.118531.

88. Ellen MacArthur Foundation. Circularity Indicators: An Approach to Measuring Circularity. *Ellen MacArthur Found* **2015**, *12*, doi:10.1016/j.giq.2006.04.004

89. Walker, S.; Coleman, N.; Hodgson, P.; Collins, N.; Brimacombe, L. Evaluating the Environmental Dimension of Material Efficiency Strategies Relating to the Circular Economy. *Sustainability* **2018**, *10*, 666, doi:10.3390/su10030666.

90. Linder, M.; Sarasini, S.; Van Loon, P. A Metric for Quantifying Product-Level Circularity. *J. Ind. Ecol.* **2017**, *21*, 545–558, doi:10.1111/jiec.12552.

91. Mitchell, S.; O'Dowd, P.; Dimache, A. Manufacturing SMEs doing it for themselves: developing, testing and piloting an online sustainability and eco-innovation toolkit for SMEs. *Int. J. Sustain. Eng.* **2019**, *13*, 159–170, doi:10.1080/19397038.2019.1685609.

92. British Standards Institution. *BSI Standards Publication Framework for Implementing the Principles of the Circular Economy in Organizations—Guide*; 2017.

93. Saidani, M.; Yannou, B.; Leroy, Y.; Cluzel, F.; Kendall, A. A taxonomy of circular economy indicators. *J. Clean. Prod.* **2019**, *207*, 542–559, doi:10.1016/j.jclepro.2018.10.014.

94. Blomsma, F.; Brennan, G. The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. *J. Ind. Ecol.* **2017**, *21*, 603–614, doi:10.1111/jiec.12603.

95. Pauliuk, S. Critical appraisal of the circular economy standard BS 8001:2017 and a dashboard of quantitative system indicators for its implementation in organizations. *Resour. Conserv. Recycl.* **2018**, *129*, 81–92, doi:10.1016/j.resconrec.2017.10.019.

96. Park, K.; Kremer, G.E. Text mining-based categorization and user perspective analysis of environmental sustainability indicators for manufacturing and service systems. *Ecol. Indic.* **2017**, *72*, 803–820, doi:10.1016/j.ecolind.2016.08.027.

97. Kravchenko, M.; Pigosso, D.C.; McAloone, T.C. Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: Consolidation of leading sustainability-related performance indicators. *J. Clean. Prod.* **2019**, *241*, 118318, doi:10.1016/j.jclepro.2019.118318.

98. Potting, J.; Hekkert, M.; Worrell, E.; Hanemaaijer, A. ; PBL Netherlands Environmental Agency, Copernicus Institute of Sustainable Development. *Circular Economy: Measuring Innovation in the Product Chain*. Policy Report; 2017.

99. Birat, J.-P. Materials, beyond Life Cycle Thinking. *Rev. Métallurgie* **2012**, *109*, 273–291, doi:10.1051/metal/2012026.

100. Garza-Reyes, J.A.; Valls, A.S.; Nadeem, S.P.; Anosike, A.; Kumar, V. A circularity measurement toolkit for manufacturing SMEs. *Int. J. Prod. Res.* **2018**, *57*, 7319–7343, doi:10.1080/00207543.2018.1559961.

101. Masi, D.; Day, S.; Godsell, J. Supply Chain Configurations in the Circular Economy: A Systematic Literature Review. *Sustainability* **2017**, *9*, 1602, doi:10.3390/su9091602.

102. Oncioiu, I.; Capusneanu, S.; Tűrkeș, M.C.; Topor, D.I.; Constantin, D.-M.O.; Marin-Pantelescu, A.; Hint, M. Ștefan The Sustainability of Romanian SMEs and Their Involvement in the Circular Economy. *Sustainability* **2018**, *10*, 2761, doi:10.3390/su10082761.

103. Dey, P.K.; Malesios, C.; De, D.; Budhwar, P.; Chowdhury, S.; Cheffi, W. Circular economy to enhance sustainability of small and medium-sized enterprises. *Bus. Strat. Environ.* **2020**, *29*, 2145–2169, doi:10.1002/bse.2492.

104. Schreier, M. *Qualitative Content Analysis in Practice*; Sage Publications: 2012.

105. Jurgensen, C.E. Selected factors which influence job preferences. *J. Appl. Psychol.* **1947**, *31*, 553–564, doi:10.1037/h0054971.

106. Daddi, T.; Nucci, B.; Iraldo, F. Using Life Cycle Assessment (LCA) to measure the environmental benefits of industrial symbiosis in an industrial cluster of SMEs. *J. Clean. Prod.* **2017**, *147*, 157–164, doi:10.1016/j.jclepro.2017.01.090.

107. Di Maio, F.; Rem, P.C. A Robust Indicator for Promoting Circular Economy through Recycling. *J. Environ. Prot.* **2015**, *6*, 1095–1104, doi:10.4236/jep.2015.610096.

Suplementary Materials

Table S1. Data collection grid

Statement	Sector	Economic Performance: Turnover(€)**	BN(€)**	RE(%)**	No. Workers	"CE" mention	Production: Mesure	Previous year	Current year	NR1*	NR2*	ER1	RM1*	RM2	RM3	RM4	RM5	RM6	EM1	EM2	EM3	WM1*	WM2*	WM3	WM4	WM5	LC1	LC2	LC3	LC4	LC5	LC6
1	Chemical/Farma	62021634	2195710	6,31	180	0	t/a	31164,1	30150,48	0	0	1	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1	0	0	0
2	Chemical/Farma	22579936	-783343	-4,37	49	0	t/a	13783,0	13037	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
3	Textile	9012862	1676952	43,56	15	0	mmp/a	36,4	47,1068636	1	0	0	0	0	0	0	1	1	0	0	1	0	0	1	1	1	1	0	1	0	1	1
4	Textile	2727791	196801	5,72	5	0	t/a	25141,0	24385	1	1	0	1	0	0	0	0	0	0	0	0	1	-	1	1	1	0	0	0	0	0	0
5	Metal	377823	5763	1,85	6	0	tmp/a	13,0	12,22	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Plastics/Rubber	17404117	4001362	26,24	44	0	t/a	255,7	520,43	0	1	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1
7	Plastics/Rubber	1673518	32255	2,25	13	0	t/a	132,8	126,4	0	1	0	0	0	0	0	1	1	1	0	1	0	1	1	1	0	0	0	1	0	0	0
8	Metal	69091370	1805287	4,38	99	1	t/a	82137,0	77353	0	1	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1
9	Chemical/Farma	4609889	349552	11,89	19	0	t/a	3608,0	3910	1	1	0	1	1	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0
10	Others	9601006	-171042	-2,06	93	0	MEF	528070006,4	635116503	0	1	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	1
11	Plastics/Rubber	24772311	2006817	13,11	75	0	t/a	27221,0	35749	1	1	0	1	1	0	0	1	-	1	0	1	-	-	0	0	0	0	0	0	0	0	1
12	Chemical/Farma	31597822	4958146	33,72	70	0	t/a	15346,0	18012	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
13	Chemical/Farma	14919240	1216151	16,89	30	0	t/a	17002,6	18510	0	1	1	1	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0
14	Others	162356000	2632000	3,73	239	0	Und/a	11573789,0	11658707	0	0	1	1	0	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0
15	Textile	14903623	609339	7,97	65	0	t/a	1769,0	2052	1	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
16	Chemical/Farma	53024748	-885906	-2,56	139	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Plastics/Rubber	52851857	1294282	3,59	240	0	t/a	7097,4	7825,4	1	1	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1	1	1	1
18	Minerals/Wood	5715488	81785	1,14	22	0	t/a	624,5	576,72	0	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1
19	Metal	14370546	452202	5	48	0	tm/a	3111,0	2681	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
20	Metal	4269648	163492	5,29	27	0	tm/a	1431,0	1528	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
21	Plastics/Rubber	26292822	3374615	22,88	125	0	tmp/a	1617,0	2240	1	1	0	-	0	0	0	1	1	0	0	1	1	1	1	1	1	0	0	1	0	0	0
22	Metal	218520000	4232000	5,09	200	0	t/a	62416,0	58621	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	1	1	0	1	0	1	1
23	Minerals/Wood	16426959	1131923	15,87	44	-	-	-	-	-	-	1	-	0	0	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1
24	Plastics/Rubber	51254334	8552188	33,33	249	0	tmp/a	5109,2	5843,670886	1	0	0	-	0	0	0	0	1	0	1	1	-	-	1	0	0	0	0	1	1	0	1
25	Chemical/Farma	12991471	142881	1,35	50	0	t/a	27885,7	26617,8	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
26	Other	74391295	643077	2,41	66	0	t/a	185260,0	185047	1	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
27	Minerals/Wood	274269000	-31295000	-3,03	145	1	t/a	1436483,0	1312726	1	0	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1
28	Chemical/Farma	53077384	1936260	2,17	200	0	t/a	481366,0	503773	0	0	1	0	0	1	1	1	0	0	2	1	0	1	1	0	1	0	0	0	0	0	0
29	Minerals/Wood	9264590	424702	4,97	38	0	t/a	128345,0	118902	1	1	1	1	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	1
30	Textile	7047097	-160019	-5,52	70	0	Und/a	328,0	384	0	1	0	1	0	0	0	0	0	0	0	1	-	0	0	0	1	0	0	0	0	0	0
31	Others	8055305	828884	5,76	44	1	t/a	896,0	1001	1	1	1	0	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1

*See Formulas

**Financial statements from SABI Database 31/12/2018

0: No/Negative 1: Yes/Positive

Table S2. Phi coefficient correlation matrix of circularity practices

	CE Practices	NR1	NR2	RE1	RM1	RM2	RM3	RM4	RM5	RM6	EM1	EM2	EM3	WM1	WM2	WM3	WM4	WM5	LC1	LC2	LC3	LC4	LC5	LC6
1	NR1 - Improved water efficiency in production	–																						
2	NR2 - Improved energy efficiency in production	-0,009 (30)	–																					
3	RE1 - Use of renewable energy	0,094 (30)	-,381* (30)	–																				
4	RM1 - Improved raw materials use efficiency in production	0,205 (30)	-0,126 (30)	-0,236 (30)	–																			
5	RM2 - Replacement of materials with renewable ones	-0,200 (30)	-0,067 (30)	0,177 (30)	-0,134 (30)	–																		
6	RM3 - Selection of biodegradable materials	-0,018 (30)	-0,306 (30)	0,094 (30)	0,018 (30)	-0,134 (30)	–																	
7	RM4 - Use of sustainable/renovable raw materials	0,089 (30)	-0,157 (30)	0,236 (30)	0,134 (30)	-0,167 (30)	0,802** (30)	–																
8	RM5 - Use of recycled/recirculated raw materials	-0,055 (30)	0,165 (30)	0,144 (30)	0,055 (30)	0,102 (30)	0,055 (30)	0,181 (30)	–															
9	RM6 - Certification/evaluation of suppliers' environmental behavior	-0,075 (29)	-0,221 (29)	-0,068 (29)	0,315 (29)	-0,139 (29)	-0,197 (29)	-0,246 (29)	0,180 (29)	–														
10	EM1 - Reduced emissions due to less extraction of raw material	-0,200 (30)	-0,067 (30)	0,177 (30)	-0,301 (30)	0,375* (30)	-0,134 (30)	-0,167 (30)	0,442* (30)	0,053 (29)	–													
11	EM2 - Reduced emissions stemming from using clean energies	-0,117 (30)	-0,161 (30)	0,463* (30)	-0,029 (30)	0,218 (30)	0,117 (30)	0,267 (30)	0,059 (30)	-0,016 (29)	0,218 (30)	–												
12	EM3 - Reduced emissions by optimizing materials/machinery/improving	0,116 (30)	-0,005 (30)	0,390* (30)	0,200 (30)	0,079 (30)	-0,169 (30)	-0,079 (30)	0,290 (30)	0,240 (29)	0,276 (30)	0,361* (30)	–											
13	WM1 - Decreased no-hazardous waste generation concerning production	0,175 (30)	0,279 (30)	-0,154 (30)	-0,175 (30)	0,218 (30)	-0,175 (30)	-0,218 (30)	0,059 (30)	-0,123 (29)	0,218 (30)	-0,111 (30)	0,017 (30)	–										
14	WM2 - Decreased hazardous waste generation concerning production	0,243 (29)	0,177 (29)	0,170 (29)	-0,243 (29)	0,018 (29)	0,009 (29)	0,125 (29)	0,347 (30)	0,203 (28)	0,358 (29)	0,247 (29)	0,153 (29)	,408* (30)	–									
15	WM3 - Waste recovery	0,191 (30)	0,081 (30)	0,107 (30)	0,111 (30)	-0,075 (30)	0,161 (30)	0,201 (30)	0,185 (30)	0,070 (29)	-0,075 (30)	0,066 (30)	0,202 (30)	0,230 (30)	0,222 (29)	–								
16	WM4 - By-products	0,111 (30)	0,071 (30)	0,053 (30)	0,040 (30)	-0,113 (30)	-0,161 (30)	0,050 (30)	0,277 (30)	0,201 (29)	0,264 (30)	0,099 (30)	0,154 (30)	0,099 (30)	0,484** (29)	0,364* (30)	–							
17	WM5 - Reintegrated waste into the internal production process	0,018 (30)	-0,033 (30)	0,342 (30)	-0,018 (30)	-0,208 (30)	0,074 (30)	0,208 (30)	0,367* (30)	-0,119 (29)	0,138 (30)	0,257 (30)	0,256 (30)	-0,196 (30)	0,098 (29)	-0,010 (30)	0,480** (30)	–						
18	LC1 - Extended product lifetime	-0,134 (30)	-0,157 (30)	0,236 (30)	0,134 (30)	-0,167 (30)	-0,089 (30)	0,259 (30)	0,408* (30)	-0,008 (29)	0,111 (30)	0,024 (30)	0,184 (30)	-0,218 (30)	-0,102 (29)	-0,050 (30)	0,302 (30)	0,438* (30)	–					
19	LC2 - Reused/refurbished/ remanufactured products	-0,018 (30)	0,234 (30)	0,094 (30)	0,018 (30)	0,200 (30)	-0,071 (30)	0,356 (30)	0,327 (30)	-0,197 (29)	0,200 (30)	0,408* (30)	0,147 (30)	0,117 (30)	0,282 (29)	0,161 (30)	0,141 (30)	0,074 (30)	0,356 (30)	–				
20	LC3 - Eco-design	0,029 (30)	-0,015 (30)	0,154 (30)	0,408* (30)	0,036 (30)	-0,175 (30)	0,024 (30)	0,356 (30)	0,297 (29)	0,036 (30)	0,048 (30)	0,361* (30)	-0,111 (30)	-0,201 (29)	0,230 (30)	0,263 (30)	0,106 (30)	0,509** (30)	0,117 (30)	–			
21	LC4 - Easy components separation	0,089 (30)	0,067 (30)	0,000 (30)	0,356 (30)	-0,167 (30)	-0,089 (30)	0,259 (30)	0,181 (30)	0,230 (29)	-0,167 (30)	0,267 (30)	0,184 (30)	-0,218 (30)	-0,102 (29)	0,201 (30)	0,050 (30)	-0,023 (30)	0,259 (30)	0,356 (30)	0,509** (30)	–		
22	LC5 - Returning materials to the factory after use	-0,299 (30)	-0,150 (30)	0,063 (30)	0,120 (30)	-0,224 (30)	0,239 (30)	0,447* (30)	0,365* (30)	0,053 (29)	0,000 (30)	-0,098 (30)	0,035 (30)	-0,293 (30)	-0,258 (29)	0,067 (30)	0,135 (30)	0,217 (30)	0,745** (30)	0,239 (30)	0,488** (30)	0,447* (30)	–	
23	LC6 - Product traceability	-0,134 (30)	-0,202 (30)	0,141 (30)	0,000 (30)	0,167 (30)	-0,267 (30)	-0,111 (30)	0,136 (30)	0,315 (29)	0,167 (30)	0,218 (30)	0,079 (30)	0,073 (30)	0,105 (29)	-0,151 (30)	0,151 (30)	-0,069 (30)	0,333 (30)	0,000 (30)	0,218 (30)	0,333 (30)	0,268 (30)	–

Correlations between practices of the same category | Correlations between practices of different categories

* The correlation is significant at the 0.05 level (bilateral). ** The correlation is significant at the 0.01 level (bilateral). (n): N Value.

Correlations between practices of the same category coloured in yellow; Correlations between practices of different categories coloured in green.

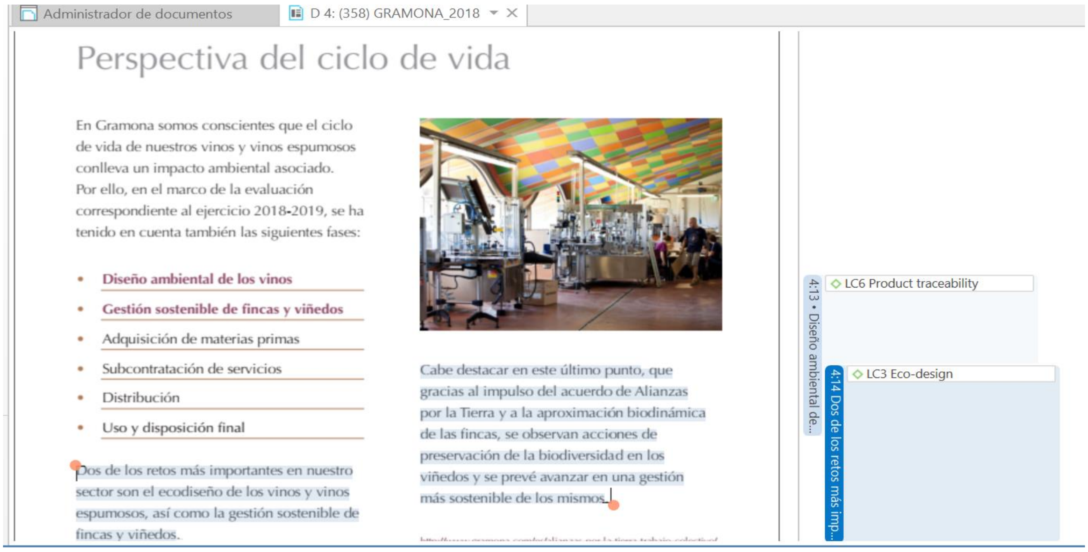

Figure S1. Example Codification 1 with Atlas.ti. Source: screenshot of document encoding in Atlas.ti (Version 8.4.24.9).

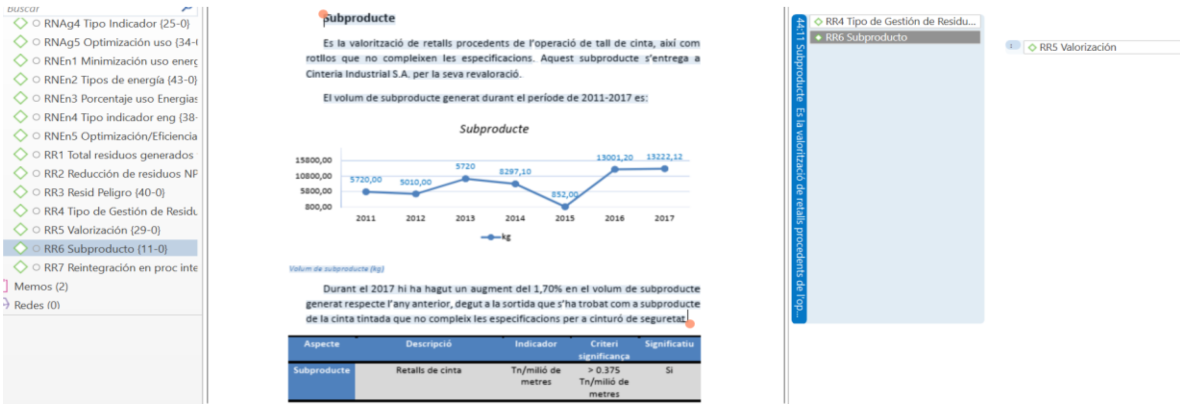

Figure S2. Example Codification 2 with Atlas.ti. Source: screenshot of document encoding in Atlas.ti (Version 8.4.24.9).

Chapter 5. EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy

This chapter is based on: Barón Dorado, A., Giménez Leal, G., de Castro Vila, R. (2022). "EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy" Journal of the Cleaner Production. http://10.1016/j.jclepro.2022.133213

EMAS ENVIRONMENTAL STATEMENTS AS A MEASURING TOOL IN THE TRANSITION OF INDUSTRY TOWARDS A CIRCULAR ECONOMY

JOURNAL OF CLEANER PRODUCTION

Alexandra Barón Dorado, Gerusa Giménez Leal, Rodolfo de Castro Vila

ABSTRACT

One of the European Commission's main objectives within its Green Deal strategy is to encourage organisations to adopt a circular economy (CE). Although the Eco-Management and Audit Scheme (EMAS) regulation is highlighted as a tool to help firms evaluate, report and improve their advances in this direction, no studies have been found that empirically validate the usefulness of EMAS as a circularity measuring tool. To address this gap, this paper analyses the information reported in the EMAS statements and determines whether it really is useful to be able to measure the level of adoption of the circular model in companies. Content analysis and statistical methods (Kendall rank correlation coefficient and Pearson's Chi-Square Test) are employed to provide empirical evidence from 122 companies. Results show that the information reported in the statements analysed is neither extensive enough nor provided as scalable and comparable quantitative data to be able to consider EMAS as a valid tool to measure and report the progress of companies in the transition towards a more circular model. Outcomes of the study have useful implications for policy makers and companies. Recommendations to regulators centre on establishing specific circular key performance indicators within the EMAS regulation, which would help companies transition towards a CE. Recommendations to managers include using EMAS reporting in a more comprehensive and indicator-focused way, which could help them visualise their current situation more clearly and be able to compare themselves to others more effectively, thus moving towards circularity in a more targeted way.

Keywords: Circular Economy, Environmental reporting, Environmental statements, Environmental Management System, Eco-Management and Audit Scheme, Industrial companies, Indicators.

5.1. Introduction

At the end of 2019, the European Commission (EC) published the European Green Deal, a strategy that aims to reduce emissions by 55% by 2030 and achieve climate neutrality by 2050 (European Commission, 2019a). In recent years, the call for a more sustainable and circular economic model has grown, and the increasing support from businesses and governments shows that it is more important than ever (Blériot, 2020). However, despite this growing interest, the global economy is currently only 8.6% circular, compared to 9.1% two years ago (Circle Economy, 2021). This negative evolution in the global circularity gap is explained by three related latent aspects: high extraction rates, continuous stockpiling and low levels of end-of-use processing and recycling.

The linear economy, understood as the traditional linear production and consumption system, and all that it entails is still deeply rooted in today's society. However, despite the slow progress towards a more circular model, positive bottom-up actions are making headway worldwide. Entrepreneurs and companies see adopting the CE model as an opportunity to increase their profit margins through resource and energy efficiency (Mazzi et al., 2016a). They believe that eco-innovation can help them create new consumer-driven markets by demanding more sustainable, environmentally friendly products (European Environment Agency, 2020). Thus, both urgency and opportunity have encouraged an increasing number of countries and national governments to begin to shape their strategies to support investment in sustainable, targeted CE agendas.

Authorities can also strengthen the demand for more sustainable goods and services through green public procurement, thus stimulating eco-innovation (European Commission, 2019b). Corporate Social Responsibility (CSR) involves taking responsibility for one's impact on society and also advocates compliance with environmental product requirements (European Commission, 2018a). The UN Global Compact, an initiative that calls on companies to actively address environmental risks and opportunities, has a strong foothold in Europe, where it has the highest total number of participants compared to other regions (United Nations Global Compact, 2018). Representatives of business and industry are also key stakeholders in the multi-stakeholder platform on the Sustainable Development Goals (SDG). This is led by the EC, the Circular Economy Stakeholder Platform and the Bioeconomy Stakeholder Panel (European Commission and The European Economic and Social Committee, 2019).

One of the debate points in the transition to a CE focuses on evaluating progress towards the model (Mayer et al., 2019) and the role of various transition enablers. Environmental performance reporting and the way in which CE should be communicated remains in need of further clarity and research. The discussion of these topics is limited within both the academic literature and the reporting approaches related to sustainability and environmental performance themselves (e.g. Global reporting initiative (GRI), British Standards Institute (BSI), Carbon Disclosure Project (CDP), World Economy Forum (WEF), Underwriters Laboratories Standards (UL) and EMAS) (Opferkuch et al., 2021). Analysing the level to which companies adopt CE principles requires comprehensive and reliable information and reporting on progress towards the circular model. The company's environmental impact is key to the satisfaction of all stakeholders. Literature has been found focusing on the development of environmental reports from different perspectives. Some studies analyse this information based on the content of their environmental accounting reports (Lehman, 2017; Liu et al., 2018; Mata et al., 2018; Russell et al., 2017). Others analyse it from the point of view of legislative compliance (Mazzi et al., 2020). Studies have also been found that analyse reports from a circular perspective, although they do not use the same analysis indicators (Ghisellini et al., 2018; Scarpellini et al., 2020; Wang et al., 2014). One study also highlights the paucity of data provided to assess and compare performance in relation to CE adoption (Dagiliene et al., 2020).

At European level, the EC supports several approaches by helping companies willing to adopt CE principles in their production processes and gradually integrate the environmental dimension into their business models. An example is the EU EMAS, an Environmental Management System (EMS) that European companies and other organisations can use to assess, report and improve their environmental performance. Environmental statements, required by the EMAS, are a reliable information source as they are approved by an external environmental verifier, and annually updated reports are ratified in well-established accreditation bodies. The EC emphasises that EMAS organisations "must assess all their environmental impacts and report on six core indicators: energy efficiency, material efficiency, water, waste, biodiversity and emissions. Because they have to be publicly reported, these Key Performance Indicators (KPIs) allow for comparison of the environmental performance of various organisations and enable public authorities to assess the progress towards a CE" (European Commission, 2017). However, although companies with EMSs such as EMAS show a higher level of awareness and sensitivity to environmental protection, and are therefore one step ahead of companies with no such scheme in place (Barón Dorado et al., 2022; Fonseca et al., 2018; Marrucci et al., 2019), there has been no evaluation of whether the available indicators are really capable of assessing progress towards the CE model.

The aim of this study is to evaluate environmental statements published by manufacturing EMAS companies and to analyse if they provide relevant information on the companies' circular practices to be considered as measurement tools for the transition towards a CE. Thus, this article contributes to the existing literature by analysing if the EMAS can be considered as a measuring tool in industry's transition towards a circular economy by a) analysing the CE practices reported by industrial firms; b) analysing differences between companies in adopting these practices; and c) analysing the KPIs of circularity revealed in the statements.

The article is structured in 6 sections. Section 2 provides a literature review of concepts linked to the relationship between CE and environmental performance reporting. Section 3 describes the methodology used to answer the research questions by using information from the environmental statements. Section 4 outlines the results. Section 5 covers the discussion, and section 6 draws the main conclusions and outlines the limitations of the study.

5.2. Literature review

5.2.1 CE practices

Although research on CE has increased in recent years, attempts to find consensus on its concept, definition and related activities are still ongoing. Practice theory describes practice as the relationship between human action and its interaction with the system (Ortner, 2006). A review of the literature on CE practices at organizational level reveals different approaches by sector, applicability or degree of implementation (Acerbi and Taisch, 2020; Govindan and Hasanagic, 2018). Although previous studies often report on objectives or intentions, they seldom investigate actual actions or performance indicators (Hopwood et al., 2005; Stewart and Niero, 2018). Furthermore, the main focus of research on the CE practices implemented in environmental reporting differs from report to report. Some of them are centred on resource efficiency, increased productivity and making use of environmental information (D'Amato et al., 2017). Other reports spotlight areas of management accounting such as material flow, life cycle assessment, or cost-benefit analysis (Dagiliene et al., 2020; Iacovidou et al., 2017). Last, some reports are associated with reusing and recycling (Stewart and Niero, 2018).

Exploring CE practices from a frame of reference delimited within the principles and concept of CE is useful. One of the reference frameworks for studying CE is classifying 10 R'imperatives or loop strategies to establish the scope of the model (Reike et al., 2018). By looking at CE practices in the various approaches to sustainability reporting that include standards, models or frameworks as tools (Opferkuch et al., 2021), different practices studied within the corporate performance and sustainability reports can be distinguished. Furthermore, the European Environment Agency (2016) offers a list of characteristics and actions that companies can consider for the transition of the model, which would enable framing practices in relation to the R'imperatives. From this perspective, the following research question emerges:

RQ1. Do companies mention circularity practices in their statements?

Several studies have addressed the topic of barriers and drivers for a CE regardless of company size (Holzer et al., 2021). They recognise considerable barriers related to high investment costs for sustainable innovations (D'Amato et al., 2020) and difficulties in obtaining financial support (Garcés-Ayerbe et al., 2019). Researchers frequently mention technical factors as another main barrier (e.g., de Jesus and Mendonça, 2018; Govindan and Hasanagic, 2018). Large enterprises (LE), which are assumed to be well endowed with the capital and human resources to achieve goals, are leading this transition (de las Casas, 2021). One of the keys to achieving progress in CE is to establish concrete and measurable objectives, and it is LE that should promote them so that sustainable initiatives around the world continue to grow and achieve greater scope. Although LE are reported to have a greater environmental impact, and are often early adopters of new reporting practices, they are also more likely to have more environmental impact (Dagiliene et al., 2020). Only large companies have previously been studied under this approach (Dagiliene et al., 2020), but it is pertinent to observe what is happening with small and medium sized enterprises (SME), which in several countries represent a large percentage of the economy.

The neo-institutional theory is taken as a theoretical framework, according to which organisations are subject to mechanisms of knowledge, dissemination and/or pressure regarding what is happening in the environment (Demirel et al., 2018), leading to processes of isomorphism between them (Martínez-Ferrero and García-Sánchez, 2017; Milne and Patten, 2002). The concept of organisational isomorphism refers to the similarity of homogenisation that can occur between different organisations (in structure, operational processes and/or behaviours). Analytically, three types of isomorphism are identified (DiMaggio and Powell, 1983), although in practice they may coexist: 1) coercive isomorphism, related to political, legislative or regulatory influences, which does not necessarily mean that pressure is exerted by force; 2) normative or cultural isomorphism, related to people's academic training and experience, which standardises their way of acting in organisations so that they come to behave in a similar way; and 3) mimetic isomorphism, in which uncertainty due to the environment or the success of other organisations, generates imitation as a mechanism to help companies make decisions and take actions under conditions of uncertainty (Daddi et al., 2016).

This research analyses mimetic isomorphism and seeks possible differences between the adoption and communication of CE practices between SME and LE, and any possible mimetic influence that the latter exert. A sub-objective linked to RQ1 is therefore proposed:

RQ1_1. Do the CE practices reported differ according to company size?

5.2.2 Environmental reporting through EMS

An EMS is defined as "a set of interrelated elements used to establish policies and objectives, and to achieve those objectives" (International Organization for Standardization, 2015). The two most widely known EMS are ISO14001 and EU EMAS. ISO14001 has been in operation since 1996 and is a private international standard developed by ISO, while the EMAS regulation was first published in 1993 and developed by the EC.

Different authors have analysed the importance of EMS in improving environmental performance, finding divided opinions. Some have found significant improvements (Clarkson et al., 2008; Giménez et al., 2003; Herbohn et al., 2014), while others indicate that improvements are difficult to quantify as a result of the relatively high degree of emphasis placed on qualitative information (Siew, 2015); because of the interpretation and implementation of these requirements in the scope of the internal dynamics of each organization can widely differ among companies (Testa et al., 2014); or as a consequence of the lack of rigorous auditing and control systems for certifications to protect and reinforce the efforts organizations make in environmental matters (Lannelongue and González-Benito, 2012). Other authors point that the statements need to be reviewed over time (Iraldo et al., 2009; Mazzi et al., 2016b; Rennings et al., 2006). Other studies also indicate that firms' motivations for incorporating an EMS may differ both by firm type and by the cultural and regulatory environment (Heras-Saizarbitoria et al., 2015; Lam et al., 2011), the latter being crucial in the need to engage firms in environmental actions. In countries with stricter regulatory laws, companies tend to adapt less EMS, or at least maintain an internal self-regulatory system, but not necessarily certify it because the marginal legitimacy benefits of certification may be quite low (Glachant et al., 2002; Prakash and Potoski, 2014; Wätzold et al., 2001). In contrast, some companies with more lax regulations might opt more to implement these systems as a way to legitimise their actions.

With the aim of deepening the content of environmental reports of an EMS, this research focuses on EMAS and not on ISO14001 for several reasons:

- EMAS depends on a public body, unlike the private ISO 14001 standard (Testa et al., 2014), which allows us a glimpse of whether public environmental policies are being reflected at the operational level, and whether EU strategies are beginning to appear in the environmental communication discourse of European companies under its coercive influence.
- EMAS imposes stringent requisites, but the rewards of voluntary participation include improved environmental performance, enhanced credibility, better compliance with legislation and increased competitiveness, and also develop a basis from which to face future economic and ecological challenges (Álvarez-García et al., 2018; Álvarez-García and del RíoRama, 2016).

- Although both EMS require environmental performance reporting, the EMAS regulation sets stricter requirements on external reporting, requiring the updating of "environmental statements" on an annual basis and their availability to different stakeholders. Additionally, it is requested that the reported data must be validated by an external verifier (European Commission, 2018b). This feature not only provides some transparency and legitimacy by openly communicating performance on significant environmental aspects (Demirel et al., 2018; Mazzi et al., 2016a), but it also allows researchers to have truthful information for their review.

- In addition to presenting indicators at the operational level on environmental accounting, environmental performance reports also allow information at the strategic level to be observed (Guenther et al., 2016) for environmental policy, improvement targets, record of achievements and other relevant information on the EMS. The fact that environmental management processes of EMAS-registered organisations are systemized puts them in a privileged position regarding circular transition, while having to report on their continuous improvement through environmental statements makes this document a potential environmental reporting tool.

5.2.3 CE and environmental reporting

Various organisations, institutions and academics began to consider alternatives that could move the industry from a linear model based on "take-make-use-recover" to a more adaptive model that considers the disposal of finite, non-renewable resources, waste tracking and emissions generated in the manufacturing process. The Ellen MacArthur Foundation (2015), for example, defines CE as a restorative model that seeks to maintain the value of products and components within the economy for as long as possible, thereby reducing over-extraction of raw materials and making use of secondary materials already within the system or which end up as waste in landfills or incineration. The number of publications addressing CE from different aspects is growing rapidly, but there are still few that address it from environmental accounting (Liu et al., 2018) and environmental performance reporting (Sassanelli et al., 2019).

In recent years, some initiatives for measuring circularity at the micro-level have emerged with different systems and types of KPIs: MFA Indicator for the mining industry (Lèbre et al., 2017); CE Assessment Index System for phosphorus chemical companies (PCFs) (Liang et al., 2018); Circularity Assessment Model for the financial sector (Giacomelli et al., 2018); and other proposals for circularity indicator systems developed by independent organisations such as the Circulytics tool of the Ellen McArthur Foundation (Ellen MacArthur Foundation, 2020) and the WBCSD Circularity Transition Indicators with KPMG (WBCSD, 2021). However, very few studies have analysed the applicability of these systems and types of indicators, or the possibility of incorporating a circular indicator into the environmental reports currently used by companies (Barón et al., 2020; Dagiliene et al., 2020; Scarpellini et al., 2020).

As Arthur Lyon-Dahl (2012) points out, indicators are only as good as the data that support them, and in this regard, the verified environmental performance information from EMAS environmental statements could be very useful to implement some measurement indicator in the transition towards circularity, which is why it is relevant to analyse what kind of information within the reports can be useful when adopting the model (Mazzi et al., 2012). Considering the nature of environmental performance reports which, in addition to "measurable results of an organisation's environmental management (Mäkelä, 2017), communicate quantitative and qualitative information on environmental impacts and consequences of relevant environmental activities that support decision making" (Latan et al., 2018; Schaltegger et al., 2017), the following research question is put forward:

RQ2. In environmental statements, are there KPIs on circularity practice that enable EMAS to be considered a measurement tool?

5.3. Material and Methods

5.3.1 Data sample

The sample selection in this research focuses on Spanish industrial companies, mainly because the study is funded by the Spanish government (Efficiency, Innovation, Competitiveness and Sustainable Business Performance research project), but also because Spain is among the countries with the highest number of EMAS-registered companies in the EU. First, access was gained to the EC's EU EMAS Helpdesk register and, in June 2019, a list of 845 EMAS-verified sites in Spain was obtained, taking the environmental statements of the production sites as a unit of analysis. Furthermore, to analyse companies that have a greater environmental impact and cover a larger number of indicators within the environmental statements, as mentioned above, 166 sites classified in Industry and Manufacturing according to NACE codes 10 to 32 were selected. This selection also considered the size of the company in line with the number of workers (OECD, 2005).

A representative sample was taken for the data analysis, establishing a confidence level of 0.95 and a margin of error of 0.05 (Suchmacher and Geller, 2012), which determined a sample size of 122 production centres throughout Spain. Of these centres, the sample was distributed according to the NACE classification by industrial sector and by company size: 57.4% SME and 42.6% LE (see table 1). The five main regions of Spain where the centres in the sample were found were also observed: Catalonia represents 29.5%, Galicia 14.8%, Madrid 12.3%, Euskadi 11.5% and Andalucía 9.8%.

Table 1. Sample Distribution

Industrial Sector	Size SME	LE	Total	%
Chemical/pharmaceutical industry	10	12	22	18%
Textile industry	6	1	7	6%
Graphic industry	7	2	9	7%
Food and beverage manufacturing	9	10	19	16%
Metallurgical industry	4	3	7	6%
Electrical and electronic equipment manufacturing	2	5	7	6%
Manufacture of machinery and equipment, except electronics	2	3	5	4%
Non-metallic mineral products industry (glass/ceramics)	6	5	11	9%
Paper industry	4	6	10	8%
Other extractive industries	3	0	3	2%
Manufacture of fabricated metal products, except machinery	6	0	6	5%
Car manufacturing	3	4	7	6%
Wood industry	1	0	1	1%
Rubber and plastic products industry	7	1	8	7%
Total	**70**	**52**	**122**	**100%**

Once the sample was defined, the environmental statements were searched for directly on the companies' websites. Where this was not successful, the web search engine was used with the following criteria: most recent environmental statements, and the keywords "company name" + "EMAS Statements/Environmental Statements" and/or "EMAS verification number" in Spanish and/or Catalan.

Of the environmental statements, only those from the year 2016 onwards were chosen, considering that the CE action plan for the European Union was published in 2015 (European Commission, 2015), coinciding with the increase in scientific publications related to the CE (Korhonen et al., 2018). Of the total sample of 122 sites, the environmental statements of 119 were found, with only 3 of not available and therefore treated as "missing".

5.3.2 Content Analysis

Starting from the theoretical basis on the different loops of the CE (Reike et al., 2018) and the key characteristics of it (European Environment Agency, 2016), a list of CE practices applicable to different types of industrial enterprises was drawn up. After a preliminary review of the practices with respect to statements, the authors created a search grid to store both qualitative and quantitative information on each of the practices. To this effect, which CE practices were most frequently mentioned in the statements were classified and selected, until those that were the most relevant for the study were defined. Other data were also recorded, such as in which statements the term 'circular economy' appeared, and the size of the companies measured by the number of employees.

An Optical Character Recognition (OCR) of the statements was performed in the review process to ensure that the documents met the selection criteria. This also facilitated the search for words and concepts. All documents were checked to ensure that they were verified by an accredited verification body and that the information was relevant, then the content analysis was used to analyse the information contained in the environmental statements. Content analysis is a research technique used to make replicable and valid inferences by interpreting and coding textual material (Krippendorff, 2004), wherein qualitative data can be converted into quantitative data by systematically evaluating texts. This methodology is valuable as it enables researchers to retrieve and examine the nuances of organisational behaviours, stakeholder perceptions and social trends. It is also an important bridge between purely quantitative and purely qualitative research methods.

EMAS statements report information through qualitative statements and quantitative facts, followed by graphs and figures (European Parliament and Council of the European Union, 2009). Thus, in this study, all information included in the documents was analysed and categorised, both at the level of declarative texts and at the level of reported quantitative data. For the declarative texts, the research team created a search grid to ensure adequate reliability and validity for the analysis (Schreier, 2012). The CE practices coding classification mentioned in the previous section was used to draw up the grid.

With reference to the quantitative data, the environmental indicators were identified from the numerical or graphic information in the companies' statements, tables, graphs and the body of the text. The CE practices sought in the documents were mostly analysed as dichotomous qualitative variables (yes/no) and as ordinal variables with respect to the number of CE practices that are reported. All the information was coded using Atlas.ti software, which was verified and discussed by the researchers to avoid errors before completing the grid with the final information.

Based on the literature review and the fact that there is still no consensus or general framework on CE practices adapted to the micro-level, and less so for the industrial sector, a mixed list of different circularity practices (European Environment Agency, 2020; Prieto-Sandoval et al., 2018) was reviewed and collated with regard to the structure of the EMAS environmental statements. Practices that are approached from the perspective of efficient resource management (e.g., efficient use of natural resources, reduction in the use of raw materials, reduction of emissions and minimisation of waste generation) were not included in the list. This is because, following the continuous improvement cycle of EMS and its primary focus on efficient management of processes and materials, these practices can be considered more of an outcome of the CE than an enabling practice. This resulted in 17 CE practices, which were divided into four groups: Materials, Energy, Waste Management and Life Cycle. In the coding, the practices that were found to be qualitative were identified with the word "text", and those with quantitative values (quantities, percentages, indices) with the word "KPI". Thus, each group contained the following variables:

- **Materials:** (M1text) Materials replaced with renewable ones; (M2text) Selection of biodegradable materials; (M3text) Use of sustainable/renewable raw materials; (M4text) Use of recycled/recirculated materials; (M5KPI) Quantification of the use of sustainable materials).
- **Energy:** (E1text) Use of renewable energies; (E2KPI) Quantification of the use of renewable energy.
- **Waste Management:** (WM1text) Waste recovery, (WM2text) By-products, (WM3text) Reintegrated waste into the internal production process.
- **Life cycle:** (LC1text) Extended product lifetime, (LC2text) Reused/refurbished/remanufactured products, (LC3text) Eco-design, (LC4text) Easy separation of components, (LC5text) Returning materials to the factory after use; and (LC6text) Product traceability.

Table 2 shows the classification of practices according to the type of information reported (Quantitative/Qualitative) and their relationship with the R-Imperatives.

Table 2. CE Practices detected

Theoretical framework 10R[1]	Code	CE practices	Type of information reported	
			Qualitative	Quantitative
R0/R7	M1text	Materials replaced with renewables ones	X	
R0/R7	M2text	Selection of biodegradable materials	X	
R1/R7	M3text	Use of sustainable/renewable raw materials	X	
R7	M4text	Use of recycled/recirculated raw materials	X	
R1/R7	M5KPI	Quantification of the use of sustainable raw material		X
R8	E1text	Use of renewable energy	X	
R8	E2KPI	Quantification of the use of renewable energy		X
R7	WM1text	Waste recovery	X	
R6/R7	WM2text	By-products	X	
R7	WM3text	Reintegrated waste into the internal production process	X	
R8	WM4KPI	Quantification of waste recovery/re-integrated		X
R1/R6	LC1text	Extended product lifetime	X	
R3/R4/R5	LC2text	Reused/refurbished/remanufactured products	X	
R0/R6/R4	LC3text	Eco-design	X	
R1/R5	LC4text	Easy separation of components	X	
R8	LC5text	Returning materials to the factory after use	X	
R0/R6	LC6text	Product traceability	X	

1. Producer oriented classification based on Reike et al. (2018): R0-Refuse; R1-Reduce; R2-Reuse; R3-Repair; R4-Refurbish; R5-Remanufacture; R6-Repurpose; R7-Recycle materials; R8-Recover energy; R9-Remine

5.3.3 Statistical analysis

The statistical analysis was carried out in three steps. First, a descriptive analysis was performed to identify the type of information used and the CE practices most reported in the environmental statements (Qualitative/Quantitative). Second, a correlation analysis was carried out to explore the relationship between the companies that mentioned the term 'Circular Economy' in their environmental statements and those that reported a higher number of CE practices, as well as the type of information used. Kendall's Tau-b coefficient was used for this, as the variables were both ordinal and categorical (Landis and Koch, 1977). This enabled the concordant and discordant ranges between factors to be determined. In practices where significant differences were found, the degree of association of proportions was observed by taking the standardised residuals to determine which groups showed a positive or negative association. In addition, the percentage contribution for each case was calculated. Last, a cross-tabulation and Pearson's Chi-Square Homogeneity test were used to compare CE practices between firm-size groups and KPIs reported in the environmental statements. The statistical treatment of the data was performed using the SPSS v25 programme.

5.4. Results

Based on the theoretical framework and following the established methodology, 17 CE practices reported by companies were identified using content analysis. In 334 cases, qualitative information was found in the statements analysed (79.33%), while quantitative information was found in only 87 cases (20.67%). The CE practices most reported were WM1text-Waste recovery (63.90%), M4text-Use of recycled/recirculated raw materials (41%), WM4KPI-Quantification of waste recovery/re-integrated (39.3%) and E1text-Use of renewable energy (38.5%). The least mentioned practices were M2text-Selection of biodegradable materials, LC1text-Extended product lifetime, LC2text-reused/refurbished/remanufactured products and LC4text-Easy Components separation, each representing 2.5% (see Figure 1).

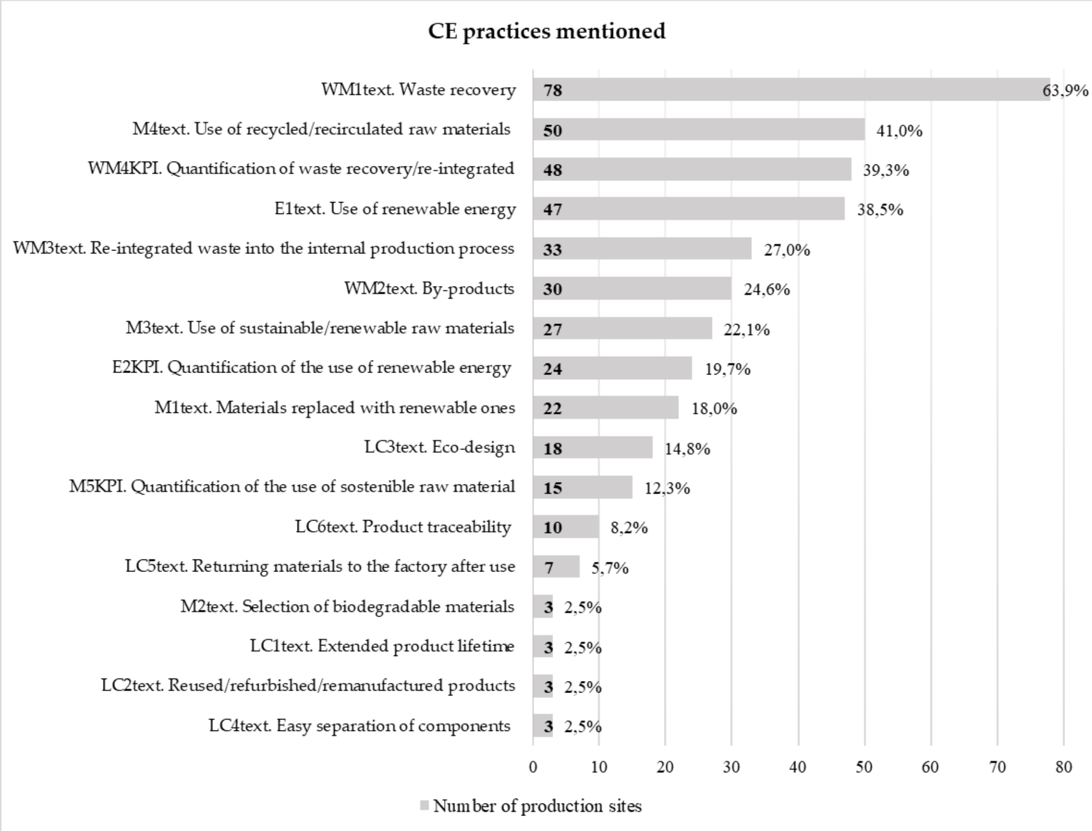

Figure 1. Frequency and percentage of CE practices

The possible relationship between companies mentioning the term 'Circular Economy' in their environmental statements and those reporting a higher number of CE practices was also explored. The statistical analysis for ordinal qualitative variables yielded a correlation value of 0.362 Kendall's Tau-b coefficient, with a significance of 0.000. Therefore, given that this figure was lower than the p-value of 0.05, there was a correlation between a higher number of reported CE practices and the mention of "circular economy" in the environmental statements.

Differences in reported CE practices according to the company size were analysed by applying Pearson's Chi-square statistical analysis to determine homogeneity between the groups. To this effect, a value of 13.354 was obtained with a significance of 0.1 (p-value of 0.05). This shows there were no significant differences in the two groups, but implementation of some practices was detected as being significantly different between them. Subsequently, a review was carried out to determine for which practices there was a stronger association between groups. The results showed that the reporting circularity practices had similar behaviour in 11 of the 17 CE practices for the two groups analysed (LE and SME), but the behaviours were not homogeneous in 6 of the 17 CE practices. The results obtained can be seen in Table 3. Additionally, the standardised residuals indicated a positive association in the LE group in 5 of the 6 cases, and only in the practice (L6text) was the association positive for SME companies.

Table 3. CE Practices with significant differences according to size

CE Practices	Chi-Square	Sig.	Association
E1text. Use of renewable energy	12.797	0.000	LE +
WM1text. Waste recovery	5.293	0.021	LE +
WM3text. Waste reintegrated into the internal production process	12.546	0.000	LE +
WM4KPI. Quantification of waste recovery/re-integrated	4.312	0.038	LE +
LC3text. Eco-design	4.548	0.033	LE +
LC6 text. Product traceability	8.317	0.004	SME +

Regarding the quantitative CE practices reported by company size, it was observed that only 1 of the 3 quantitative practices (WM4KPI, p-value 0.038) had different behaviour in relation to company size. The number of LE that reports this practice adoption is higher than the number of SME. Last, by obtaining a value of 0.274 with a significance of 0.002 by Kendall's Tau-b coefficient test (less than the p-value of 0.05), there was a correlation between the number of quantitative CE practices reported and the mention of "circular economy" within the statements.

5.5. Discussion

According to Korhonen et al. (2018), many recently published works have focused on more advanced stages of the adoption of the circularity model, but very few studies focus on the paradigm introduction. In fact, he also insists on the importance of using more qualitative research methodologies to address the first stages and the incorporation of practices from the new model. This paper analysed the information provided by the companies in the sample under these considerations.

Regarding RQ1, in the qualitative analysis of the EMAS statements, it was observed that the CE practices most mentioned by the companies were those related to Waste recovery, Use of recycled or recirculated raw materials, and the Use of renewable energy. Other practices that were crucial in the circular model, such as Reused/refurbished/remanufactured products and Extended product lifetime, were hardly mentioned, in line with the findings of Acerbi et al. (2021). In relation to differences in reported CE practices according to company size, for RQ1_1 no significant difference between the number of CE practices implemented in firms between LE and SME groups was found. This means that although it can be assumed that LE may have more resources and tools to initiate the transition to circularity, SME may have an advantage in terms of the ability to react and adapt certain practices. Of the 17 practices identified in this study, the Chi-square statistical test concluded that in only 6 of them was adoption behaviour significantly different between LE and SME. In 5 of them, LE are the main adopters of these practices, and only in the case of product traceability are SME the main adopters. This behaviour could be because SME can maintain a longer contact with their final customers, which allows the producer-manufacturer to follow up until the end of the product's life.

Regarding RQ2, and in line with the findings of Dagliene et al. (2020), the study shows that the information reported by EMAS companies in their statements is not extensive enough, nor is it based on scalable and comparable quantitative data. Specifically, the study analysed whether there was any quantification of the information expressed in percentages or units. In this context, only three quantified practices were found (Quantification of sustainable raw material $M5_{KPI}$, Quantification of use of renewable energy $E2_{KPI}$ and Quantification of waste recovery/re-integrated $WM4_{KPI}$), corresponding to 20.6% of the total number of practices observed. This indicates the limited or inconsistent CE reporting by companies in the EMAS statements and the impossibility of considering this European regulation as a tool for measuring circularity at this time.

Last, the information collected from the environmental statements not only allowed us to know the level of familiarity of industrial enterprises with the term 'circular economy', but it also revealed that the its introduction is still at a very early stage. Of the observed sample, 18.8% of the companies mentioned the term in their statements, compared to 78.6% who did not. We have found out companies that mention the term 'circular economy' coincide with those that adopt a greater number of CE practices. This could indicate that a greater dissemination of the circularity model in companies could speed up the transition towards the new paradigm, and that greater knowledge of the CE model mainly among the company's workers could act as an accelerating normative force in the incorporation of a greater number of practices and intensity of their adoption.

Limitations of the study are, first, that only companies in the industrial and manufacturing sector were considered. Second, the range of years analysed (2016-2019) should perhaps be extended as many of the policies focused on promoting circularity among companies were implemented from 2015 onwards. Nevertheless, in 2017 the EC had already stated that the EMAS Statements should contain 6 core indicators valid for assessing circularity at the micro-level (European Commission, 2017). Third, the keywords selected in the content analysis could limit the data, in that while a company may not necessarily report CE practices in its environmental statement, this does not mean that it is not carrying out actions in this direction.

5.6. Conclusions

The study carried out contributes to the theoretical landscape as it is the first study that empirically analyses the content of the environmental statements of EMAS companies with the aim of studying whether the information reported can be useful as a tool to measure the circularity of a company.

The paper concludes that the information reported by EMAS companies in their environmental statements is not extensive enough nor is it based on scalable and comparable quantitative data to be able to consider this regulation as a tool to help firms evaluate, report, and improve their advances in the transition towards a circular economy. EMAS could be a great ally in the new challenge of moving towards circularity, but before proposing to companies that they adopt complex systems of circularity KPIs, efforts should be made to expand the use of indicators for implementing circularity practices. Environmental statements according to EMAS would solve some of the drawbacks mentioned by Testa et al. (2014), such as data reliability and data availability. However, the authors believe that the results of this study show that harmonisation and comparability of data remains a challenge. Therefore, it is important to introduce specific modular and scalable circular KPIs into the EMAS regulation, starting from simple measurements and taking advantage of the current state of performance measurements. Having a system for measuring circularity at micro-level, in addition to helping each company implement objectives and improve actions, would provide meso and macro-level actors with useful information for decision-making, designing action plans and drawing up political agendas in accordance with the objectives proposed in the Circular Plan 2030 (European Commission, 2019a; Ministerio de Economía Industria y Competitividad, 2018). Further efforts are needed to move the CE model from a theoretical and conceptual level to a practical level.

Recommendations to regulators centre on boosting their coercive leverage to encourage companies to use standardising indicator statements. This would improve their measurement mechanisms, which in turn would help companies transition towards a CE. Results show that the companies most informed on CE mention a higher number of practices, and also include quantitative data in their environmental statements. This fact potentially facilitates the adoption of CE indicators. Regarding institutional theory, based on the coercive influence of an EMS regulated by the EC and reflected in corporate environmental reports, the need to promote communication of the CE, both internally and externally, is highlighted, as well as the lack of precise measurement and evaluation requirements for circularity practices.

Moving from simply mentioning circularity objectives within environmental reports to actually measuring them is crucial, and using indicators make it easier to ascertain progress, both in terms of number of actions and the rate at which they are being adopted. Recommendations to managers focus on using and reporting EMAS reporting in a more comprehensive and indicator-focused way to visualise their current situation more clearly, and to compare themselves with others more efficiently, thus moving towards circularity in a more targeted way.

Valuable conclusions can be drawn from this research; however, its generalisability is limited. A future line of research would be to replicate the study in different geographic regions, which would provide valuable insights, as well as serve validation purposes. The cost/benefit assessment of CE requires a long-term perspective, so this research could be extended by carrying out a longitudinal study.

References

Acerbi, F., Sassanelli, C., Terzi, S., Taisch, M., 2021. A systematic literature review on data and information required for circular manufacturing strategies adoption. Sustain. 13, 1–27. https://doi.org/10.3390/SU13042047

Acerbi, F., Taisch, M., 2020. A literature review on circular economy adoption in the manufacturing sector. J. Clean. Prod. 273. https://doi.org/10.1016/j.jclepro.2020.123086

Álvarez-García, J., del Río-Rama, M. de la C., Saraiva, M., Ramos Pires, A., 2018. The influence of motivations and barriers in the benefits. An empirical study of EMAS certified business in Spain. J. Clean. Prod. 185, 62–74. https://doi.org/10.1016/j.jclepro.2018.03.023

Álvarez-García, J., del RíoRama, M. de la C., 2016. Sustainability and EMAS: Impact of motivations and barriers on the perceived benefits from the adoption of standards. Sustain. 8. https://doi.org/10.3390/su8101057

Baron, A., de Castro, R., Giménez, G., 2020. Circular Economy practices among industrial EMAS-Registered SMEs in Spain. Sustain. 12, 1–28. https://doi.org/10.3390/su12219011

Barón Dorado, A., Giménez Leal, G., de Castro Vila, R., 2022. Environmental policy and corporate sustainability: The mediating role of environmental management systems in circular economy adoption. Corp. Soc. Responsib. Environ. Manag. 1–13. https://doi.org/10.1002/csr.2238

Blériot, J., 2020. The Covid-19 recovery requires a resilient circular economy | by Ellen MacArthur Foundation | Circulate | Medium [WWW Document]. Ellen MacArthur Found. URL https://medium.com/circulatenews/the-covid-19-recovery-requires-a-resilient-circular-economy-e385a3690037 (accessed 3.9.21).

Circle Economy, 2021. The Circularity Gap Report 2021.

Clarkson, P.M., Li, Y., Richardson, G.D., Vasvari, F.P., 2008. Revisiting the relation between environmental performance and environmental disclosure: An empirical analysis. Accounting, Organ. Soc. 33, 303–327.

D'Amato, D., Droste, N., Allen, B., Kettunen, M., Lähtinen, K., Korhonen, J., Leskinen, P., Matthies, B.D., Toppinen, A., 2017. Green, circular, bio economy: A comparative analysis of sustainability avenues. J. Clean. Prod. 168, 716–734.

D'Amato, D., Veijonaho, S., Toppinen, A., 2020. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. For. Policy Econ. 110, 101848. https://doi.org/10.1016/J.FORPOL.2018.12.004

Daddi, T., Testa, F., Frey, M., Iraldo, F., 2016. Exploring the link between institutional pressures and environmental management systems effectiveness: An empirical study. J. Environ. Manage. 183, 647–656. https://doi.org/10.1016/j.jenvman.2016.09.025

Dagiliene, L., Frendzel, M., Sutiene, K., Wnuk-Pel, T., 2020. Wise managers think about circular economy, wiser report and analyze it. Research of environmental reporting practices in EU manufacturing companies. J. Clean. Prod. 274, 121968. https://doi.org/10.1016/j.jclepro.2020.121968

Dahl, A.L., 2012. Achievements and gaps in indicators for sustainability. Ecol. Indic. 17, 14–19.

de Jesus, A., Mendonça, S., 2018. Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy. Ecol. Econ. 145, 75–89. https://doi.org/10.1016/J.ECOLECON.2017.08.001

de las Casas, J., 2021. La economía circular se abre paso en la estrategia de las empresas | Economía [WWW Document]. Expansión. URL https://www.expansion.com/economia/2021/06/18/60cbc620e5fdea4d408b45c8.html (accessed 9.19.21).

Demirel, P., Iatridis, K., Kesidou, E., 2018. The impact of regulatory complexity upon self-regulation: Evidence from the adoption and certification of environmental management systems. J. Environ. Manage. 207, 80–91. https://doi.org/10.1016/j.jenvman.2017.11.019

DiMaggio, P.J., Powell, W.W., 1983. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. Am. Sociol. Rev. 48, 147. https://doi.org/10.2307/2095101

Ellen MacArthur Foundation, 2020. Circulytics - measuring circularity [WWW Document]. URL https://www.ellenmacarthurfoundation.org/resources/apply/circulytics-measuring-circularity (accessed 5.24.21).

Ellen MacArthur Foundation, 2015. Growth within: a circular economy vision for a competitive europe, Ellen MacArthur Foundation.

European Commission, 2019a. The European Green Deal, European Commission. https://doi.org/10.1017/CBO9781107415324.004

European Commission, 2019b. 'Green Public Procurement' [WWW Document]. URL https://ec.europa.eu/environment/gpp/index_en.htm (accessed 4.9.21).

European Commission, 2018a. Corporate social responsibility & Responsible business conduct [WWW Document]. URL https://ec.europa.eu/growth/industry/sustainability/corporate-social-responsibility_en (accessed 4.9.21).

European Commission, 2018b. COMMISSION REGULATION (EU) 2018/2026 of 19 December 2018 amending Annex IV to Regulation (EC) No 1221/2009 of the European Parliament and of the Council on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS). Eur. Comm. 2016, 48–119.

European Commission, 2017. Moving towards a circular economy with EMAS, Circular Economy Strategy. Roadmap. Luxemburg. https://doi.org/10.2779/463312

European Commission, 2015. Closing the loop - An EU action plan for the Circular Economy.

European Commission, The European Economic and Social Committee, 2019. European Circular Economy Stakeholder Platform [WWW Document]. URL https://circulareconomy.europa.eu/platform/ (accessed 4.9.21).

European Environment Agency, 2020. The European environment-state and outlook 2020. Knowledge for transition to a sustainable Europe, Publications Office of the European Union, 2019. https://doi.org/10.15196/TS600305

European Environment Agency, 2016. Circular economy in Europe: Developing the knowledge base, European Environment agency. https://doi.org/10.2800/51444

European Parliament, Council of the European Union, 2009. REGULATION (EC) No 1221/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission De.

Fonseca, L.M., Domingues, J.P., Pereira, M.T., Martins, F.F., Zimon, D., 2018. Assessment of circular economy within Portuguese organizations. Sustain. 10, 1–24. https://doi.org/10.3390/su10072521

Garcés-Ayerbe, C., Rivera-Torres, P., Suárez-Perales, I., Hiz, D.I.L.D. La, 2019. Is it possible to change from a linear to a circular economy? An overview of opportunities and barriers for european small and medium-sized enterprise companies. Int. J. Environ. Res. Public Health 16. https://doi.org/10.3390/ijerph16050851

Ghisellini, P., Ji, X., Liu, G., Ulgiati, S., 2018. Evaluating the transition towards cleaner production in the construction and demolition sector of China: A review. J. Clean. Prod. 195, 418–434. https://doi.org/10.1016/j.jclepro.2018.05.084

Giacomelli, J., Kozamernik, D., Lah, P., 2018. Evaluating and monitoring circularity.

Giménez, G., Casadesús, M., Valls, J., 2003. Using environmental management systems to increase firms' competitiveness. Corp. Soc. Responsib. Environ. Manag. 10, 101–110. https://doi.org/10.1002/csr.32

Glachant, M., Schucht, S., Bültmann, A., Wätzold, F., 2002. Companies' participation in EMAS: The influence of the public regulator. Bus. Strateg. Environ. 11, 254–266. https://doi.org/10.1002/BSE.333

Govindan, K., Hasanagic, M., 2018. A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. Int. J. Prod. Res. 56, 278–311. https://doi.org/10.1080/00207543.2017.1402141

Guenther, E., Endrikat, J., Guenther, T.W., 2016. Environmental management control systems: a conceptualization and a review of the empirical evidence. J. Clean. Prod. 136, 147–171.

Heras-Saizarbitoria, I., Arana, G., Boiral, O., 2015. Exploring the dissemination of environmental certifications in high and low polluting industries. J. Clean. Prod. 89, 50–58. https://doi.org/10.1016/j.jclepro.2014.10.088

Herbohn, K., Walker, J., Loo, H.Y.M., 2014. Corporate Social Responsibility: The Link Between Sustainability Disclosure and Sustainability Performance. Abacus 50, 422–459. https://doi.org/10.1111/ABAC.12036

Holzer, D., Rauter, R., Fleiß, E., Stern, T., 2021. Mind the gap: Towards a systematic circular economy encouragement of small and medium-sized companies. J. Clean. Prod. 298, 126696. https://doi.org/10.1016/j.jclepro.2021.126696

Hopwood, B., Mellor, M., O'Brien, G., 2005. Sustainable development: mapping different approaches. Sustain. Dev. 13, 38–52. https://doi.org/10.1002/SD.244

Iacovidou, E., Velis, C.A., Purnell, P., Zwirner, O., Brown, A., Hahladakis, J., Millward-Hopkins, J., Williams, P.T., 2017. Metrics for optimising the multi-dimensional value of resources recovered from waste in a circular economy: A critical review. J. Clean. Prod. 166, 910–938.

International Organization for Standardization, 2015. ISO 14001:2015(en), Environmental management systems — Requirements with guidance for use [WWW Document]. ISO14001:2015. URL https://www.iso.org/obp/ui/#iso:std:iso:14001:ed-3:v1:en (accessed 9.19.21).

Iraldo, F., Testa, F., Frey, M., 2009. Is an environmental management system able to influence environmental and competitive performance? The case of the eco-management and audit scheme (EMAS) in the European union. J. Clean. Prod. 17, 1444–1452.

Korhonen, J., Nuur, C., Feldmann, A., Birkie, S.E., 2018. Circular economy as an essentially contested concept. J. Clean. Prod. 175, 544–552. https://doi.org/10.1016/J.JCLEPRO.2017.12.111

Krippendorff, K., 2004. Content Analysis: An Introduction to Its Methodology, Fourth Edi. ed. Sage Publications, Inc., Los Angeles.

Lam, P.T.I., Chan, E.H.W., Chau, C.K., Poon, C.S., Chun, K.P., 2011. Environmental management system vs green specifications: How do they complement each other in the construction industry? J. Environ. Manage. 92, 788–795.

Landis, J.R., Koch, G.G., 1977. The Measurement of Observer Agreement for Categorical Data. Biometrics 33, 159. https://doi.org/10.2307/2529310

Lannelongue, G., González-Benito, J., 2012. Opportunism and environmental management systems: Certification as a smokescreen for stakeholders. Ecol. Econ. 82, 11–22.

Latan, H., Chiappetta Jabbour, C.J., Lopes de Sousa Jabbour, A.B., Wamba, S.F., Shahbaz, M., 2018. Effects of environmental strategy, environmental uncertainty and top management's commitment on corporate environmental performance: The role of environmental management accounting. J. Clean. Prod. 180, 297–306.

Lèbre, É., Corder, G., Golev, A., 2017. The Role of the Mining Industry in a Circular Economy: A Framework for Resource Management at the Mine Site Level. J. Ind. Ecol. 21, 662–672. https://doi.org/10.1111/jiec.12596

Lehman, G., 2017. The language of environmental and social accounting research: The expression of beauty and truth. Crit. Perspect. Account. 44, 30–41.

Liang, W. zhang, Zhao, G. yan, Hong, C. shou, 2018. Performance assessment of circular economy for phosphorus chemical firms based on VIKOR-QUALIFLEX method. J. Clean. Prod. 196, 1365–1378. https://doi.org/10.1016/j.jclepro.2018.06.147

Liu, G., Yin, X., Pengue, W., Benetto, E., Huisingh, D., Schnitzer, H., Wang, Y., Casazza, M., 2018. Environmental accounting: In between raw data and information use for management practices. J. Clean. Prod. 197, 1056–1068. https://doi.org/10.1016/j.jclepro.2018.06.194

Mäkelä, M., 2017. Trends in environmental performance reporting in the Finnish forest industry. J. Clean. Prod. 142, 1333–1346.

Marrucci, L., Daddi, T., Iraldo, F., 2019. The integration of circular economy with sustainable consumption and production tools: Systematic review and future research agenda. J. Clean. Prod. 240, 118268. https://doi.org/10.1016/j.jclepro.2019.118268

Martínez-Ferrero, J., García-Sánchez, I.M., 2017. Coercive, normative and mimetic isomorphism as determinants of the voluntary assurance of sustainability reports. Int. Bus. Rev. 26, 102–118. https://doi.org/10.1016/J.IBUSREV.2016.05.009

Mata, C., Fialho, A., Eugénio, T., 2018. A decade of environmental accounting reporting: What we know? J. Clean. Prod. 198, 1198–1209. https://doi.org/10.1016/J.JCLEPRO.2018.07.087

Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., Blengini, G.A., 2019. Measuring Progress towards a Circular Economy: A Monitoring Framework for Economy-wide Material Loop Closing in the EU28. J. Ind. Ecol. 23, 62–76. https://doi.org/10.1111/JIEC.12809

Mazzi, A., Mason, C., Mason, M., Scipioni, A., 2012. Is it possible to compare environmental performance indicators reported by public administrations? Results from an Italian survey. Ecol. Indic. 23, 653–659. https://doi.org/10.1016/J.ECOLIND.2012.05.006

Mazzi, A., Spagnolo, M., Toniolo, S., 2020. External communication on legal compliance by Italian waste treatment companies. J. Clean. Prod. 255, 120325. https://doi.org/10.1016/j.jclepro.2020.120325

Mazzi, A., Toniolo, S., Manzardo, A., Ren, J., Scipioni, A., 2016a. Exploring the direction on the environmental and business performance relationship at the firm level. Lessons from a literature review. Sustain. 8. https://doi.org/10.3390/su8111200

Mazzi, A., Toniolo, S., Mason, M., Aguiari, F., Scipioni, A., 2016b. What are the benefits and difficulties in adopting an environmental management system? The opinion of Italian organizations. J. Clean. Prod. 139, 873–885. https://doi.org/10.1016/j.jclepro.2016.08.053

Milne, M.J., Patten, D.M., 2002. Securing organizational legitimacy: An experimental decision case examining the impact of environmental disclosures. Accounting, Audit. Account. J. 15, 372–405. https://doi.org/10.1108/09513570210435889

Ministerio de Economía Industria y Competitividad, 2018. Circular Economy Spanish Strategy 'España Circular 2030', Exacutive Summary.

OECD, 2005. OECD Annual Report 2005.

Opferkuch, K., Caeiro, S., Salomone, R., Ramos, T.B., 2021. Circular economy in corporate sustainability reporting: A review of organisational approaches. Bus. Strateg. Environ. 30, 4015–4036. https://doi.org/10.1002/BSE.2854

Ortner, S.B., 2006. Anthropology and Social Theory: Culture, Power, and the Acting Subject. Anthropol. Soc. Theory. https://doi.org/10.1215/9780822388456

Prakash, A., Potoski, M., 2014. Global Private Regimes, Domestic Public Law: ISO 14001 and Pollution Reduction. Comp. Polit. Stud. 47, 369–394. https://doi.org/10.1177/0010414013509573

Prieto-Sandoval, V., Ormazabal, M., Jaca, C., Viles, E., 2018. Key elements in assessing circular economy implementation in small and medium-sized enterprises. Bus. Strateg. Environ. 27, 1525–1534. https://doi.org/10.1002/bse.2210

Reike, D., Vermeulen, W.J.V., Witjes, S., 2018. The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. Resour. Conserv. Recycl. 135, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

Rennings, K., Ziegler, A., Ankele, K., Hoffmann, E., 2006. The influence of different characteristics of the EU environmental management and auditing scheme on technical environmental innovations and economic performance. Ecol. Econ. 57, 45–59.

Russell, S., Milne, M.J., Dey, C., 2017. Accounts of nature and the nature of accounts: Critical reflections on environmental accounting and propositions for ecologically informed accounting. Accounting, Audit. Account. J. 30, 1426–1458. https://doi.org/10.1108/AAAJ-07-2017-3010

Sassanelli, C., Rosa, P., Rocca, R., Terzi, S., 2019. Circular economy performance assessment methods: A systematic literature review. J. Clean. Prod. 229, 440–453. https://doi.org/10.1016/j.jclepro.2019.05.019

Scarpellini, S., Marín-Vinuesa, L.M., Aranda-Usón, A., Portillo-Tarragona, P., 2020. Dynamic capabilities and environmental accounting for the circular economy in businesses. Sustain. Accounting, Manag. Policy J. 11, 1129–1158. https://doi.org/10.1108/SAMPJ-04-2019-0150

Schaltegger, S., Burritt, R., Petersen, H., 2017. An introduction to corporate environmental management: Striving for sustainability.

Schreier, M., 2012. Qualitative Content Analysis, in: Flick, U. (Ed.), The SAGE Handbook of Qualitative Data Analysis. pp. 170–183.

Siew, R.Y.J., 2015. A review of corporate sustainability reporting tools (SRTs). J. Environ. Manage. 164, 180–195. https://doi.org/10.1016/J.JENVMAN.2015.09.010

Stewart, R., Niero, M., 2018. Circular economy in corporate sustainability strategies: A review of corporate sustainability reports in the fast-moving consumer goods sector. Bus. Strateg. Environ. 27, 1005–1022. https://doi.org/10.1002/bse.2048

Suchmacher, M., Geller, M., 2012. Step 7: Correlating Sample Data with the General Population – 95% Confidence Interval, Practical Biostatistics. Elsevier. https://doi.org/10.1016/b978-0-12-415794-1.00010-0

Testa, F., Rizzi, F., Daddi, T., Gusmerotti, N.M., Frey, M., Iraldo, F., 2014. EMAS and ISO 14001: The differences in effectively improving environmental performance. J. Clean. Prod. 68, 165–173. https://doi.org/10.1016/j.jclepro.2013.12.061

United Nations Global Compact, 2018. Progress Report.

Wang, P.C., Che, F., Fan, S.S., Gu, C., 2014. Ownership governance, institutional pressures and circular economy accounting information disclosure: An institutional theory and corporate governance theory perspective. Chinese Manag. Stud. 8, 487–501. https://doi.org/10.1108/CMS-10-2013-0192

Wätzold, F., Bltmann, A., Eames, M., Lulofs, K., Schucht, S., 2001. EMAS and regulatory relief in Europe: Lessons from national experience. Eur. Environ. 11, 37–48. https://doi.org/10.1002/EET.249

WBCSD, 2021. Circular Transition Indicators.

Chapter 6. Practising more circular economy: enabling configurations of technological and managerial practices in the manufacturing industry

Barón Dorado, A., Ligthart, P. E. M., Witjes, S., "Practising more circular economy: enabling configurations of technological and managerial practices in the manufacturing industry" paper is about to be submitted to Resources, Conservation and Recycling.

PRACTISING MORE CIRCULAR ECONOMY: ENABLING CONFIGURATIONS OF TECHNOLOGICAL AND MANAGERIAL PRACTICES IN THE MANUFACTURING INDUSTRY

RESOURCES CONCERVATION & RECYCLING

Alexandra Barón Dorado, Paul E.M. Ligthart, Sjors Witjes

ABSTRACT

Although CE literature mainly focuses on technologies contributing to enabling more circular economy, some of these papers also suggest managerial practices associated with CE. Enhancing the understanding of the link between CE and enabling practices, this paper explores enabling configurations of supportive technologies and practices discussed in CE literature using an extensive database of the European Manufacturing Survey on innovation and sustainability practices in the manufacturing industry. Using the QCA methodology, analyses show multiple consistent configurations of technologies and management practices implemented by the 288 manufacturing companies. The results show that a wide range of technologies related to CE in combination with managerial practices can lead to the adoption of more CE in manufacturing companies. While this research adds the configuration-of-practices lens to debates on CE adoption by companies, the outcomes provide production managers with more insight into which configurations technologies and enabling managerial practices contribute to CE adoption.

Keywords: Circular Economy, Configurational Approach, Manufacturing Companies, European Manufacturing Survey

6.1 Introduction

In recent decades, the necessity to find solutions to mitigate climate change, biodiversity loss, and resource scarcity by implementing sustainable production systems has catalysed research in different disciplines and fields of study. The Circular Economy (CE) has emerged as an approach that offers solutions for migrating the existing production system toward closed-loop production/consumption patterns (Geissdoerfer et al., 2017) primarily aiming for more efficient use of natural resources (Moraga et al., 2022). CE focuses on value retention of products, materials, and components, and how these can be maintained longer while decreasing high rates of waste generation (Witjes & Lozano, 2016). CE has become part of debates on public policies or corporate strategies as a "new perspective," which has fostered academic contributions critically defining and testing the factors that drive or hinder the adoption of CE by the different societal actors (de Jesus & Mendonça, 2018).

For corporate actors, adoption of CE involves practices at both technical and organisational management level (Lieder & Rashid, 2016). Adoption of CE is hindered by difficulties such as complexity in the incorporation-transformation in existing manufacturing processes, high costs associated with new technologies, lack of adequate information in redesigning products and manufacturing processes, time in the disassembly chain, and quality compromises (de Jesus & Mendonça, 2018; Hartley et al., 2022; Kirchherr et al., 2018). Moreover, supporting management practices lack training, communication, and cooperation between companies and industries, and are confronted with challenges such as varying degrees of exposure to information, and flow of communication among the various actors aiming for contribution to CE (Bag & Pretorius, 2022; Jaeger & Upadhyay, 2020).

CE literature shows a focus mainly on the adoption of [often single] CE technologies, with few studies that consider in-depth an adoption of enabling management practices. To enhance the understanding of CE adoption by the manufacturing industry, this article focuses on two primary aspects: first, reviewing technologies and management practices that coincide in the CE literature; and second, reviewing and validating the resulting configurations using practices applied to innovation in the manufacturing industry. The outcomes of this study will allow production managers in organisations to review the practices they are currently undertaking and, in some instances, to reconfigure their organisational systems and production processes if they seek to advance their contribution to CE. It also proposes to academics, from a methodological perspective, to connect 'novel' concepts of CE with more widely studied fields, such as innovation and organisational management.

The paper is divided into 5 sections. The literature review section reviews CE literature on studies combining the use of CE technologies with management practices leading to propositions on consistent configurations of practices contributing to CE adoption. The methods section presents the European Manufacturing Survey (EMS) containing data on innovation and sustainability practices of 288 Dutch and Spanish manufacturing companies, and the QCA methodology analyses the presence of consistent CE configurations. The findings section presents the QCA findings. And finally, discussion and conclusions are drawn from the research conducted.

6.2 Organisational practices contributing to a Circular Economy

The current production system based on the process chain of take-make-use-dispose faces significant challenges to synchronizing with several Sustainable Development Goals, e.g., SDG 12 on Responsible Consumption and Production (COM 2016) 736 Final, 2016;

Rodríguez-Antón et al., 2022). CE as a sustainable development initiative to reduce the linear material and energy flows of societal production and consumption systems, by applying renewable and cascading material cycles and energy flows (Korhonen et al., 2018b), can help to face these challenges and transform the merely linear process chain. In aiming for more efficient use of the resources by closing cycles-- on the input side, limiting access to resources, as well as forecasting material shortages in the short and medium-term, and, on the output side, preventing high volumes of waste from ending up in landfills or incinerators, as well as those that might otherwise go directly into ecosystems without prior treatment thereby increasing pollution rates (Korhonen et al., 2018a). Taking nature's cycles as a reference, circularity considers cycles or cyclical flows in which "waste" is once again considered a raw material and where the maximum efficiency of the materials involved is achieved. CE is also based on the conformation of loops within the model that seeks to extend the useful life of products and materials. Underlying the relevance of practices closing the loops, we define Circular Economy as a socioeconomic system of technologies and practices aiming at the efficient use of resources and retention of value throughout the life cycle of products and services (Reike et al., 2018).

6.2.1 CE in the manufacturing industry

In the manufacturing industry, CE adoption can be realized by increasing the durability of the value of products, reducing inputs and use of natural resources, reducing the loss of valuable materials, and reducing the level of emissions (Sousa-Zomer et al., 2018). One common denominator of CE adoption by companies is the increased interest in value retention: introducing products and components in cascade systems or loops, hereinafter called Value Retention Options (VRO), that retain their value for a longer period, reducing negative externalities and increasing their efficiency (Reike et al., 2018; Russell & Nasr, 2020). Value retention has been studied within the manufacturing industry generally as incremental innovations or improvements, mainly within direct reuse, repair, and refurbishment of existing products. Previous approaches have attempted to analyse cycles within production and supply chains, copying the role of nature in creating efficient solutions applied to the industry through strategies, tactics, and operational policies (Turken et al., 2020); industrial ecology (Ayers, 1994; Chertow, 2000; Yu et al., 2013), eco-industrial systems (Conticelli & Tondelli, 2014; Lowe et al., 1996); and clean production (Tucker, 2017).

Although cascade systems or VRO are interlinked, Reike et al., (2018) differentiate three main groups: the short ones that are closer to the customer or user, the long ones that are further away, and where products have lost their original function. Considering VRO from the producer's perspective, the state of development cycles can vary according to the type of industry, external conditions, policies, and micro-level objectives. In the short cycle, where the imperatives of Refuse (R0), Reduce (R1) and Reuse (R2) manufacturing companies have focused mainly on the implementation of resource-efficient actions and processes, as well as on increasing productivity. Only in the last few years has eco-design (Dahmani et al., 2021) and re-thinking of products gained higher attention (Bhaskaran & Gilbert, 2015; Jensen et al., 2021; Shevchenko & Kronenberg, 2020). In the middle cycle, activities related to Repair (R3), Refurbish (R4), Re-manufacture (R5) and Re-purpose (R6) continue to require more attention from the industry, either by direct intervention or by supporting third parties to facilitate their integration (Bocken et al., 2014; Centobelli et al., 2020). In the long cycle, although the actions related to Re-cycle (R7) and Recover (R8) are most widely recognized at the enterprise level and discussed in the literature, these actions continue to require greater efforts to move from purely waste management to the implementation of more advanced processes for this purpose (Do et al., 2021; Segura-Salazar et al., 2019). The Re-mine loop (R9) requires more intervention targeting public policies and administrations for its implementation.

When looking at industrial production processes involving products and materials, four main CE principles can be highlighted (Sousa-Zomer et al., 2018), i.e.,

(i) increase the durability of the value of products;

(ii) reduce input and use of natural resources;

(iii) reduce the loss of valuable materials; and

(iv) reduce the level of emissions.

As CE is not limited to technical implementation but has fundamental organisational implications (Reike et al., 2018), the CE principles can be better understood when divided over the organisational production stages (see Table 1):

Table 1. Organisational production stages, CE principles and CE Value Retention Options (VRO)

Stages *(When)*	CE Principles *(What)*	CE value retention options *(How)*
Stage 1. Pre-production	(i-ii)	R0, R1, R2, R5, R7, R8
Stage 2. Production	(iii-iv)	R1, R2, R7, R8
Stage 3. Extension and retention of value	(i-iv)	R0, R1, R2, R3,R4,R5, R7, R8

CE Principles; Product (i) increase the value durability of products; Materials: (ii) reduce input and use of natural resources; Production processes: (iii) reduce the loss of valuable materials; (iv) reduce the level of emissions.

where increasing the durability of the product value (i.e., CE principle i) and the reduction of inputs and use of natural resources (i.e. CE principle ii) are determined before the actual production (i.e., pre-production stage), the reduction of the loss of valuable materials (i.e. CE principle iii) can be determined during the production as it entails scrap or waste reduction (i.e. production stage). To address cascade systems or long-term value retention, reducing negative externalities and increasing their efficiency (Russell & Nasr, 2019) the combination of the four CE principles can be used as a final overall stage 3 (i.e., Extension and retention of value). Thus, when understanding CE in the manufacturing industry a 'when' (i.e., production stage), a 'what' (i.e., CE principle) and a 'how' (i.e., VRO to closing loops) can be identified.

Table 1. Organisational production stages, CE principles and CE Value Retention Options (VRO)

Stages *(When)*	CE Principles *(What)*	CE value retention options *(How)*
Stage 1. Pre-production	(i-ii)	R0, R1, R2, R5, R7, R8
Stage 2. Production	(iii-iv)	R1, R2, R7, R8
Stage 3. Extension and retention of value	(i-iv)	R0, R1, R2, R3, R4, R5, R7, R8

CE Principles; Product (i) increase the value durability of products; Materials: (ii) reduce input and use of natural resources; Production processes: (iii) reduce the loss of valuable materials; (iv) reduce the level of emissions.

6.2.2 CE technologies and organisational practices

Analysing the CE technologies implemented by companies, a non-exhaustive literature review of CE was conducted, considering empirical studies and literature reviews in line with the CE principles (Acerbi & Taisch, 2020; Govindan & Hasanagic, 2018). Some of these studies can be traced back to technological and organisational practices previously studied as sustainability practices (Fu, 2019).

As for the technologies we found, i.e.,

- End-of-pipe (Demirel & Kesidou, 2011),
- Recycling (Cainelli et al., 2015),
- Material and energy efficiency (Antonioli et al., 2013; Demirel & Kesidou, 2011),
- Emission reduction (Antonioli et al., 2013), and
- Technical, environmental practices (Fu, 2019).

Added sources of practices are seen as in line with the principles of circularity, i.e.,

- Recycling Technologies (Alvarez-de-los-Mozos & Renteria, 2017; Bendikiene et al., 2019; Scarpellini & Romeo, 1999; Smol et al., 2015),
- Additive Manufacturing (Byard et al., 2019; Clemon & Zohdi, 2018; Despeisse et al., 2017; Garmulewicz et al., 2018; Giurco et al., 2014),
- Cleaner and Green Technologies (Bhandari et al., 2019; Shi et al., 2008),
- Lean design (Dahmani et al., 2021),
- Waste recovery technologies (Alvarez-de-los-Mozos & Renteria, 2017; Helmer Pedersen & Conti, 2017; Lahtela & Kärki, 2018),
- Remanufacturing Technologies (Alvarez-de-los-Mozos & Renteria, 2017),
- Cloud Manufacturing (Fisher et al., 2018), and
- Tracking technologies (Minunno et al., 2018) open up new perspectives for actions that contribute to both cycle closure processes and to maintaining the value and reducing the extraction of primary materials (Acerbi & Taisch, 2020).

To organisational practices related to technologies, we find

- Information and education (Aragón-Correa, 1998),

- Modern and voluntary prevention (Byard et al., 2019; Clemon & Zohdi, 2018; Despeisse et al., 2017; Garmulewicz et al., 2018; Giurco et al., 2014),
- Managerial environmental practices (Fu, 2019), and
- Inter-organisational managerial practices (Armbruster et al., 2008).

In the area of circularity, management practices were also detected with an emphasis on education and communication, such as

- Establishment of effective communication, Support of all partners to develop awareness and new skills (Ünal et al., 2019),
- Leadership and commitment from the top management (Moktadir et al., 2018; Siemieniuch et al., 2015), and
- Green Human Resources Management considering Recruiting, Involving as facilitators in the process of CE transition (Marrucci et al., 2021).

Finally, the environmental management systems are considered, taking into account their two divergent characteristics (Marrucci et al., 2019): *Effectiveness* which focuses on actions taken to increase the company's operational performance, and *Legitimacy*, which seeks to increase the validity of actions towards stakeholders (Leseure et al., 2004; Voss, 2005). In total, 16 technological and managerial practices were detected (see table 2 in Appendix 1).

6.2.3 CE configurations involving organisational management practices

The theoretical approach of organisational configurations as "a multidimensional constellation of conceptually distinct characteristics that commonly occur together" (Meyer et al., 1993) is appropriate in understanding how transformations unfold. On the other hand, as commented by Jørgensen (2012), "the dimensions of performance focus on actual events, whether discursive, organisational or material and contribute to the triggers of transformations and their orchestration". There are some studies that combine different multidisciplinary technological and managerial aspects for the development of CE (Ünal et al., 2019), starting from research streams on industrial ecology, sustainable supply chain, product as a service and C2C design and addressing an interdisciplinary approach from approaches of circular economy, social psychology and organisational behaviour. Nevertheless, Ünal et al., (2019) and Lieder and Rashid (2016) emphasize the need for a systemic and holistic view and multidisciplinary approaches that address the very complex and multifaceted nature of CE.

Abernathy & Utterback's (1978) A-U model of on the management of technology and innovation mentions the importance of an adequate articulation in transitions in production processes to reduce uncertainty about the target and technology. It indicates that such uncertainty can be reduced by appropriate coordination and control methods that are adapted with the standardisation of products and production processes, i.e., "to deal with complexity by reducing the need for information processing." Yet, the literature is still limited in studying the application of CE practices together and spanning different dimensions. Fu (2019) compared the implication of measures in technical practices and management practices, showing that technical practices seek to adhere to legal environmental requirements and regulations, while management practices seek long-term change in a more consistent way. Furthermore, Lieder and Rashid (2016) noted that the technological level is at a more advanced stage, which would allow the implementation of CE at larger scales, as opposed to the levels of change management and managerial mindset required for the transition, which may still be lagging.

Several observations can be made by looking at the CE technologies and practices detected in the CE literature reviewed, see Table 2 in Appendix 1. First, CE practices applied by manufacturing firms concern practices related to technologies focused on maximising resource efficiency and organisational management practices enabling and coordinating work processes in organisations. In several empirical studies, it was observed that where technological practices were analysed in more detail, organisational practices are often mentioned as drivers or enablers of CE adoption in production. Second, the CE practices observed in the studies are mainly applied and analysed independently or with similar practices.

Two main organisational management practices mentioned in the CE studies concern training and communication. The study by Agyabeng-Mensah et al., (2021) considered the effect of intra -and inter-organisational learning on lean manufacturing, lean product development and zero waste practices, as well as the influence of organisational practice on CE performance objectives. Jaeger & Upadhyay (2020) observed the adoption behaviour of communication-focused organisational practices in large and small manufacturing firms. They found that although large firms have the necessary knowledge to develop circularity-focused strategies, they take longer to disseminate information and communications to subsidiaries. Likewise, if one of these large manufacturing companies establishes a production policy focused on circular economy and sets as one of its objectives the remanufacturing of components, it will require the use of technology and processes focused on disassembly, as well as tests of adaptability and quality of the materials or recirculated parts. In addition, the same objective will require organisational practices from the preparation and technical training to carry out specific tasks, to the communication strategy for its different subsidiaries. Practices such as the standardisation of VRO-related production processes or the creation of EC-related indicators will also be involved. It is essential to look at the different dimensions to determine the required characteristics, not only at the technological level but also in organisational practices, i.e. what individuals do within the organisation (Jarzabkowski & Spee, 2009).

We therefore synthesise the organisational management practices found into two main groups, i.e. organisational learning and production operations (see Table 3). Organisational learning comprises management activities concerning

a) Knowledge where the knowledge of the organisation (management, administrative and technical levels, in their general and specific tasks regarding the implementation of circularity processes) is relevant, as well as the knowledge of buyers/users and society in general about the circular economy (Alvarez-de-los-Mozos & Renteria, 2017; Dahmani et al., 2021; Fisher et al., 2018; Garmulewicz et al., 2018; Lahtela & Kärki, 2018);

b) Training and skill development like the way of transmitting knowledge within the organisation (Alvarez-de-los-Mozos & Renteria, 2017);

c) Production policy regarding the tools used to facilitate decision making, information flows (Dahmani et al., 2021; Fisher et al., 2018; Garmulewicz et al., 2018; Shi et al., 2008);

d) Human resources considering the management and incorporation of personnel with a high level of skills related to specific tasks focused on processes and products that consider circularity principles (Bhandari et al., 2019; Garmulewicz et al., 2018) ,

e) Information and the effectiveness of the message transmitted both intra- and inter-organisationally (Sousa-Zomer et al., 2018). Management practices concerning production operations involved

f) Quality Process to establish indicators and improvement systems that consider circularity, (Bendikiene et al., 2019; Giurco et al., 2014);

g) Manual operation for the integration of tasks, combination of planning operations, operation and control of human-machine functions (Alvarez-de-los-Mozos & Renteria, 2017; Lahtela & Kärki, 2018);

h) Production cooperation in effective coordination between supply chain partners and support among stakeholders (Chhimwal et al., 2021; Sousa-Zomer et al., 2018);

i) Leadership and commitment to set objectives, lead the team in achieving results and provide support (Bhandari et al., 2019);

j) Management systems, and

k) Government Support and Legality in the support of institutions and organisations in the transition to the model (Fisher et al., 2018).

Table 3 summarizes the combinations of CE technologies and accompanying management practices found in the different empirical studies involving manufacturing and production companies.

Table 3. Combining managerial and technological practices in empirical manufacturing studies

				Managerial practices (CE)									
				Organizational learning					Production operations				
Stages *(When)*	CE Principles *(What)*	CE Value retention options *(How)*	CE Technologies	Knowledge	Training and Skill development	Production policy	Human resources	Information	Quality Process	Manual operation	Production Cooperation	Management Systems	Government support and legality
Stage 1. Pre-production	(i)	R0, R1, R2, R5, R7	Ecodesign					x				x	
	(i)	R0, R1, R2, R5, R7	Product design	x	x								
	(i)	R1, R2, R7, R8	Lean design					x				x	
	(ii)	R1, R2	Secondary materials	x	x								
Stage 2. Production	(iii)	R1, R2, R7, R8	Clean production	x	x	x	x	x	x		x	x	x
	(iii)	R1, R2, R7, R8	Additive Manufacturing	x	x						x	x	
	(iii)	R1, R2, R7, R8	Cloud manufacturing				x						
Stage 3. Extension and retention of value	(i) (iii)	R0, R1, R2, R5, R7	Remanufacturing	x	x					x			
	(i-iv)	R1, R2, R7, R8	Recycling	x	x					x			
	(i, ii, iv)	R1, R2, R7, R8	Waste recover	x	x					x			
	(iii)	R1, R2, R7, R8	Tracking technnologies										

6.2.4 Configuration prepositions

According to the above, we observe that the literature suggests specific interrelations of practices focused on CE adoption that also present variations depending on the state of production to which they belong. In order to validate the configurations found considering CE principles and VRO, we propose the following propositions:

P1. The Pre-Production stage for the CE is configured by the Product Design, Eco-design, Lean Design and Secondary materials technologies (Technologies) and Knowledge, Training, Flows information and Environmental Management system (Management Practices)

P2. The production stage for the CE is configured by Clean Production technologies, Additive and Cloud Manufacturing (Technologies) and Knowledge, Training, Human Resources, Information, Production Policy, Quality Process, Management Systems, Government Support and Production Cooperation (Management Practices).

P3. The extension and retention value stage for the CE is configured by Remanufacture, Recycling, Waste Recovery and Tracking Technologies and Knowledge, Training and Manual Operation (Management Practices).

6.3 Methodology

6.3.1 Study sample

The sample consists of 288 cases representing manufacturing firms in the Netherlands (70.5%) and Spain (29.5%). The empirical data used to test the propositions were collected of the 2018 European Manufacturing Survey. This is an international questionnaire developed by the Fraunhofer Institute for Systems and Innovation Research (ISI) in 1993 (Lay & Maloca, 2004) that has been updated every three years since then. The survey assesses the adoption of managerial and technological practices implementation by manufacturing companies together with other aspects of business innovation. Although the survey does not make a specific reference to direct questions on Circular Economy, its wide range of innovative technologies and organisational practices related to sustainability and work practices allows delimiting those related to circularity. The survey sample comprises manufacturing establishments (NACE codes 10-33) with at least 10 employees (median of 45 employees). A questionnaire was sent both by post to the top management, followed by a reminder, and phone call two weeks later. Table 4 summarizes sample characteristics. The control variables considered for this study were company size and type of industry.

Table 4. Sample characteristics of manufacturing firms (N= 288)

	Total (%)	Netherlands (%)	Spain (%)
Sample	100	70.5	29.5
Firm size			
0-19	13.9	17.2	5.9
20-99	66.3	67.0	64.7
100-249	15.3	12.8	21.2
250 or more	4.5	3.0	8.2
Industry			
Metal	17.1	19.7	10.8
Food	11.5	8.4	19.3
Textile	16.4	14.3	21.7
Construction	3.1	2.5	4.8
Chemical	12.6	12.8	12.0
Machinery	19.9	19.2	21.7
Electronic	19.2	23.2	9.6

6.3.2 Analysis framework and variables

The theoretical framework discussed above revealed a total of 21 technologies and managerial practices. Applying this framework to the European Manufacturing Survey, we obtained 20 indicators capturing these technologies and practices applied by the manufacturing firms (see Table 5 in appendix 2). Two management practices, i.e., Management Environmental Systems and Government Support, share the same variable, i.e., certified environmental management system (e.g., ISO14001 and/or EMAS). An environmental management system such as EMAS can be related to this practice due to its coercive influence as it is regulated by the European Commission (Barón Dorado et al., 2022).

We conducted a crisp-set Qualitative Comparative Analysis (Ragin, 2006) which employs a Boolean (AND/OR) logic to examine the asymmetric relationship between all available combinations, the so-called sets, of multiple binary conditions and an outcome variable. The QCA analysis is appropriate to analyse the hypothesized relationships between specific combinations of the technology and management practices (being conditions) and the outcome variable CE being the total number CE technologies in use by the manufacturing firms. Following the Boolean logic a condition can be present as well as absent in a set indicated by capital letters and lower-case letters respectively. The method evaluates the necessity of each condition to produce the outcome and examines the sufficiency of sets resulting in a reduced number of sets consistent with the given outcome. The analysis is performed using the Fuzzy procedure in Stata 17.1 Longest & Vaisey (2008) which enables a significance test of positive (or negative) associations between a set of conditions given the initial truth table and the outcome variable. Following the standard QCA procedure of Boolean minimization (Roig-Tierno et al., 2017) which eliminates the so-called irrelevant sets, the remaining minimum sets are evaluated on the extent sets are congruent with the outcome, as indicated by the coverage coefficient, and the extent the outcome is sufficiently mapped by the sets, as indicated by the sufficiency coefficient. The outcome variable 'CE' ranging between 0.0-12.0 technologies used (mean of 4.81, stdev 2.33) was transformed into a percentile score standardized to range from 0 to 1 (see Table 5).

6.4 Results

6.4.1 Descriptive statistics

An overview of the single CE technologies reviewed management practices and their matching EMS variables is presented in Table 5 (see appendix 2). The adoption of the single CE technologies varies across manufacturing firms ranging from 8.7% (Additive Manufacturing: use of 3D-printing) and 9.4% (Clean production: use of Secondary Materials) -both production stage 2 technologies- to 67.0% (Lean design: use of Production Planning) situated in production stage

1. Application of specific management practices vary from 29.9% (Environmental Management System: CertifiedEnvMS), 30.2% (Production Cooperation: CollProduction) to most popular supporting Human Resource like staff loyalty programs (58.0%). As shown in literature overview Table 3, seven CE technologies are mainly production stage 1 technologies, five are stage 2 technologies, and six are used in production stage

2. Interesting to note that most organisational learning focussed CE management practices appear in multiple production stages, such as Knowledge (RD) and Training and Skills development (JobTraining).

6.4.2 Prepositions

While the propositions suggest specific configurations of CE technologies and management practices. Given the selected outcome variable CE (number of CE technologies adopted), it is expected that many stage 1 CE technologies (A-G) will incorporate in the final configurations. The propositions suggest that these technologies will be matched by the hypothesized management practices specified per production stage.

The pre-production proposition (P1) matches 11 CE-practices of which 7 are technologies and 4 management practices. The QCA procedure resulted in a minimum configuration reduction set of 11 out of the 14 significant practice configurations having an overall consistency of 0.753 and a coverage of 0.167 involving 31 (10.7%) manufacturing firms (see Table 6). All 11 configurations show an individually significant solution consistency with the outcome variable CE ranging from 0.643 to 0.936, although their unique coverages are low, i.e., ranging from 0.009 to 0.035.

The listed configurations are mainly characterized by 9 CE practices; five of the 7 technologies and 4 management practices. The technologies with the highest presence in the configurations:

A: Eco-design (ProdEnvInno),

E: Lean Design (Assemble2Order),

F: Lean Design (ProdPlanning),

and a medium presence of D: Lean Design (Make2Order), and

G: Secondary Materials (SecMaterials).

All management practices show a notable presence in the sets:

H: Knowledge (RD),

I: Training and skills development (JobTraining),

J: Information (DisplayBoards), and

K: Environmental management systems/governmental support and legality (CertifiedEnvMS). The presence of many management practices matching CE technologies is consistent with the pre-production proposition. Interesting to note that the two CE technologies that are included indicate the more generically applicable technologies than the technologies not included in the emerging CE configurations such as Product design (VirReality, Prototype3D).

Table 6. Final Reduction Set, stage 1 Pre-production (given significant high outcome CE)

Set	Coverage	Consistency
a*b*c*d*E*F*G*h*i*J*K	0.009	0.643
a*b*C*D*e*F*g*h*i*J*k	0.014	0.668
A*b*c*d*e*F*g*h*I*J*K	0.022	0.771
A*b*c*d*e*F*G*H*I*j*K	0.010	0.695
A*b*c*d*E*F*g*H*i*j*k	0.014	0.668
A*b*c*d*E*F*G*h*I*j*k	0.013	0.936
A*b*c*d*E*F*G*h*I*J*K	0.011	0.771
A*b*c*D*e*F*g*H*i*J*k	0.014	0.653
A*B*c*d*E*F*g*H*I*J*k	0.012	0.834
A*B*C*D*e*F*g*H*I*J*k	0.012	0.834
b*c*D*e*F*g*H*I*J*K	0.035	0.808
Total	0.167	0.753

Technologies: 4 mngt(H-K) practices: A: Eco-design (ProdEnvInno), B: Product design (VirReality), C: Product design (Prototype3D), D: Lean design (Make2Order), E: Lean design (Assemble2Order), F: Lean design (ProdPlanning), G: Secondary materials (SecMaterials),

Management practices: H: Knowledge (RD), I: Training and Skills development (JobTraining), J: Information (DisplayBoards), K: Environmental Management systems/ Government support and legality (CertifiedEnvMS).

The second Production stage proposition (P2) combines 5 CE technologies with 8 management practices. The QCA procedure resulted in a minimum configuration reduction set of 4 out of the 5 significant practice configurations having an overall consistency of 0.810 and a coverage of 0.070 involving 12 (4.2%) manufacturing firms (see Table 7). All four configurations show an individually significant solution consistency with the outcome variable CE ranging from 0.758 to 0.849. Their unique coverages are low, i.e., ranging from 0.012 to 0.013.

The listed configurations are characterized mainly by six CE practices, i.e., two CE technologies:

B: Clean production (CleanProdData),

E: Cloud manufacturing (RealtimeControl) - and four matching management practices -

G: Training and Skills development (JobTraining),

I: Human resources (StaffLoyalty),

J: Information (DisplayBoards),

K: Quality Process (QualityMeasures).

In line the Production stage proposition, most of the management practices are included in the majority of configurations, except for the practice Production Cooperation (L), which appears only in one configuration.

Although the management practices cover both types of managerial practices, i.e., organisational learning as well as production operational practices, not many CE technologies are involved in most configurations of the final solution. For the included CE technologies, the availability of Clean Production and Cloud Manufacturing is dominant which underlines the relevance of data-producing technologies in the Production Stage.

Table 7. Final Reduction Set, stage 2 Production (given significant high outcome CE)

Set	Unique Coverage	Solution Consistency
a*B*c*d*e*f*G*h*I*J*K*L*M	0.012	0.849
a*B*c*D*E*f*G*h*I*j*k*l*m	0.012	0.849
a*B*c*d*E*F*G*H*I*J*K*l	0.012	0.758
a*B*c*d*E*F*G*H*I*J*K*M	0.013	0.784
Total	0.070	0.810

Technologies: A: Secondary materials (SecMaterials), B: Clean production (CleanProdData), C: Additive Manufacturing (Print3D), D: Cloud manufacturing (DigExchange), E: Cloud manufacturing (RealtimeControl),
Management practices: F: Knowledge (RD), G: Training and Skills development (JobTraining), H: Production policy (WorkInstruction), I: Human resources (StaffLoyalty), J: Information (DisplayBoards), K: Quality Process (QualityMeasures), L: Production Cooperation (Collproduction), M: Environmental Management systems/ Government support and legality (CertifiedEnvMS)

The Extension and retention value stage proposition (P3) for the third proposition couples the six stage 3 technologies to three management practices. The QCA procedure resulted in a minimum configuration reduction set of 10 out of the 17 significant practice configurations having an overall consistency of 0.756 and a coverage of 0.242 involving 45 (15.6%) manufacturing firms (see Table 8). All 10 configurations show an individually significant solution consistency with the outcome variable CE ranging from 0.643 to 0.887. Their unique coverages are low, i.e., ranging from 0.009 to 0.047.

In line with the proposition, all the three management practices appear in the majority of configurations, i.e., two having an organisational learning focus, one production operation focus. Regarding technological practices, only one does not seem to be predominant: Tracking Technologies. Remanufacturing Practice, together with Water and Energy Recycling Technologies seem to dominate the co-incidence of these three management practices in the Extension and Retention production stage.

Table 8. Final Reduction Set, stage 3 Extension and retention of value (given significant high outcome)

Set	Unique Coverage	Solution Consistency
a*b*c*D*e*f*g*H*I	0.009	0.643
a*b*C*D*E*f*g*H*I	0.013	0.887
A*B*C*d*e*f*G*h*i	0.011	0.806
a*b*c*d*e*F*H*I	0.024	0.679
a*b*C*d*e*f*g*h	0.018	0.643
a*b*C*e*f*G*H*I	0.020	0.774
a*b*C*D*e*f*G*H	0.013	0.867
B*c*d*e*f*G*H*I	0.020	0.707
A*B*c*d*E*f*G*i	0.025	0.727
A*B*c*d*E*f*H	0.047	0.826
Total	0.242	0.756

Technologies: A: Remanufacturing (Modernization), B: Remanufacturing (Maintenance), C: Recycling (SusWater), D: Recycling (SusEnergy), E: Waste recover (TakeBack), F: Tracking technologies (PLCsystems),
Management practices: G: Knowledge (RD), H: Training and Skills development (JobTraining), I: Manual operation IntegrationTasks)

Figure 1 summarized the emerging configurations containing the most relevant CE technologies and enabling management practices for each production stage.

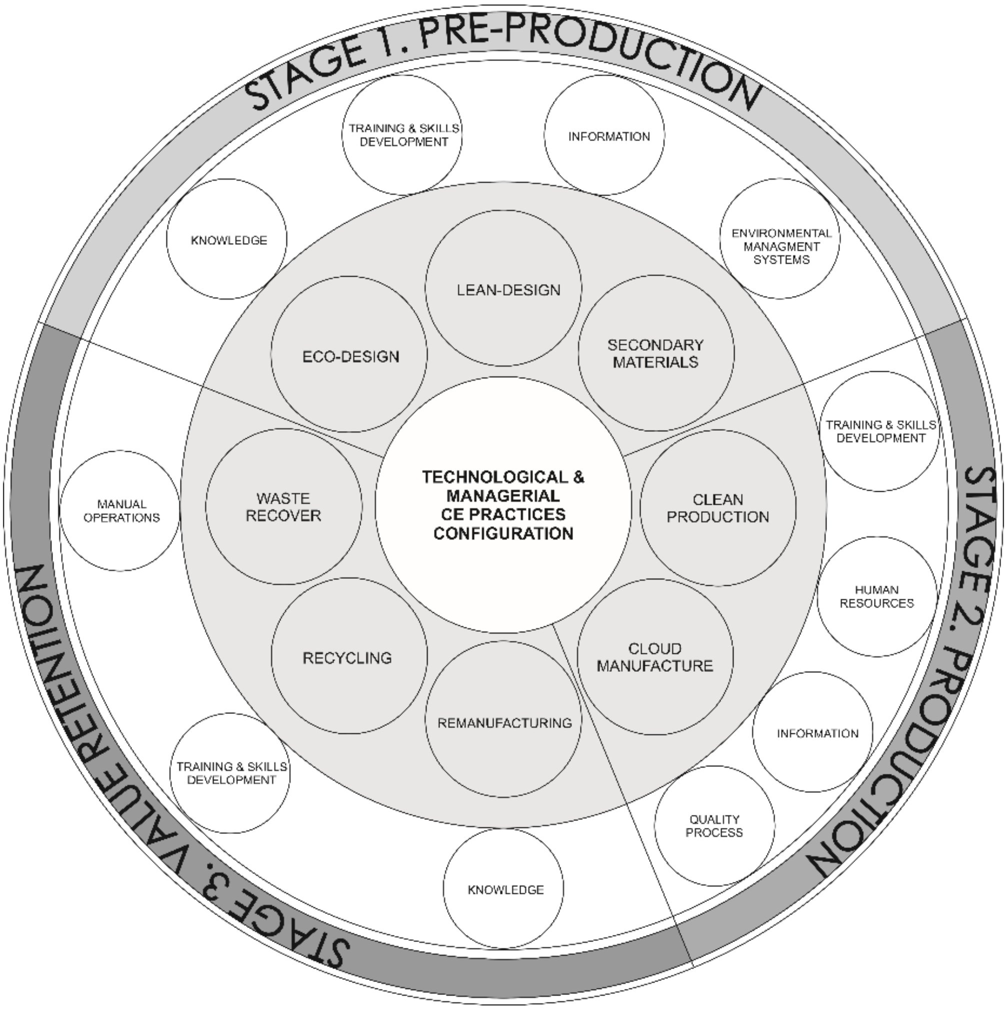

Fig 1. Technological and managerial practices with most presence in configurations

6.5 Discussion and Conclusions

The study of circularity involves increasing challenges. From the academic field, it represents the difficulty of transferring complex and theoretical models to the practice field in an effective and agile way. Also, in the organisational field, it represents the challenge of identifying, within the broad spectrum of practices used and available, which facilitate the route to circularity in production processes. The number of studies analysing CE technologies in combination with management practices needs to be increased (see Table 1) in which the enabling function of practices (Dahmani et al., 2021; Garmulewicz et al., 2018) is studied in more detail.

Following the call by, among many, Reike et al, (2018) and Ünal et al, (2019) for more research on management practices in combination with technological practices that enable CE adoption, this paper firstly identified the most determinant organisational and technological practices in CE depending on the production status. When delimiting the principles of CE, contradiction and conflict were detected in the literature. Therefore, one of this study's contributions is understanding the 'When', 'What', and 'How' in the adoption of CE in the manufacturing sector.

Then, adopting the lens of configurations, it was obtained that CE technologies and management practices seem to operate in specific combinations that also depend on the stage of their production process (see Figure 1). Moreover, findings show that in the Pre-production and Value Retention stages, as suggested by P1 and P3, respectively, CE technologies prevail over managerial practices. The opposite is the case in the Production stage, where managerial practices are more relevant than technologies within the detected configurations. A common finding in each stage is the relevance of training employees on CE and related technologies. Knowledge, particularly about implementing circularity processes, is relevant in the pre-production and value retention stages.

Despite the high levels of overall consistency, the findings indicate multiple consistent pathways by which configurations are associated with more CE adoption reaffirming what was observed by Alvarez-de-los-Mozos & Renteria (2017), Dahmani et al., (2021); Garmulewicz et al., (2018) and Sousa-Zomer et al., (2018). Manufacturing companies have not found a standard configuration of technologies and management practices prevailing at each stage of the production process. It may be due to the industrial sector and firm size, which could be further investigated in future research. Thus, the research shows that the combinations presented here for each production stage are a good starting point for adopting CE in companies in the manufacturing sector and reveal which practices require more emphasis in their application.

Among the limitations of this study, we find:

a) The central focus of the EMS survey is on organisational and technological innovation; it does not have a primary focus on circularity. However, from a methodological point of view, it is interesting to rely on more widely studied fields with which organisations are more familiar such as innovation.

b) The configuration of associated technologies and organisational practices, not implying causal (in either direction) relationships with CE. Moreover, although the empirical results of this study are supported by high consistency, the configurations coverage levels are low, indicating the impact of multiple other factors at play, such as the industrial sector or the type of production system.

Therefore, we encourage replication of the validation of the propositions and, thus, of the configurations mentioned here in further studies focusing on circularity.

This research empowers managers, administrators, and decision-makers in organisations with better ideas on approaching their goal of adopting CE principles. First, it shows the importance of combining/shaping management and technological practices to achieve the set objectives in general and adopting the CE principles in particular. It also shows that companies adopt CE principles while striving for optimization and innovation of production processes in the manufacturing industry.

References

Abernathy, W. J., & Utterback., J. M. (1978). Patterns of Industrial Innovation. *Technology Review*, *80*(7), 41–47.

Acerbi, F., & Taisch, M. (2020). A literature review on circular economy adoption in the manufacturing sector. *Journal of Cleaner Production*, *273*, 123086. https://doi.org/10.1016/j.jclepro.2020.123086

Agyabeng-Mensah, Y., Tang, L., Afum, E., Baah, C., & Dacosta, E. (2021). Organisational identity and circular economy: Are inter and intra organisational learning, lean management and zero waste practices worth pursuing? *Sustainable Production and Consumption*, *28*, 648–662. https://doi.org/10.1016/J.SPC.2021.06.018

Alvarez-de-los-Mozos, E., & Renteria, A. (2017). Collaborative Robots in e-waste Management. *Procedia Manufacturing*, *11*, 55–62. https://doi.org/10.1016/J.PROMFG.2017.07.133

Antonioli, D., Mancinelli, S., & Mazzanti, M. (2013). Is environmental innovation embedded within high-performance organizational changes? the role of human resource management and complementarity in green business strategies. *Research Policy*, *42*(4), 975–988. https://doi.org/10.1016/J.RESPOL.2012.12.005

Aragón-Correa, J. A. (1998). Strategic proactivity and firm approach to the natural environment. *Academy of Management Journal*, *41*(5), 556–567. https://doi.org/10.2307/256942

Armbruster, H., Bikfalvi, A., Kinkel, S., & Lay, G. (2008). Organizational innovation: The challenge of measuring non-technical innovation in large-scale surveys. *Technovation*, *28*, 644–657. https://doi.org/10.1016/j.technovation.2008.03.003

Ayers, Robert. U. (1994). Industrial Metabolism: Theory and Policy. In *The Greening of Industrial Ecosystems* (pp. 21–37).

Bag, S., & Pretorius, J. H. C. (2022). Relationships between industry 4.0, sustainable manufacturing and circular economy: proposal of a research framework. *International Journal of Organizational Analysis*, *30*(4), 864–898. https://doi.org/10.1108/IJOA-04-2020-2120

Barón Dorado, A., Giménez Leal, G., & de Castro Vila, R. (2022). EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy. *Journal of Cleaner Production*, *369*, 133213. https://doi.org/10.1016/j.jclepro.2022.133213

Bendikiene, R., Ciuplys, A., & Kavaliauskiene, L. (2019). Circular economy practice: From industrial metal waste to production of high wear resistant coatings. *Journal of Cleaner Production*, *229*, 1225–1232. https://doi.org/10.1016/J.JCLEPRO.2019.05.068

Bhandari, D., Singh, R. K., & Garg, S. K. (2019). Prioritisation and evaluation of barriers intensity for implementation of cleaner technologies: Framework for sustainable production. *Resources, Conservation and Recycling*, *146*, 156–167. https://doi.org/10.1016/J.RESCONREC.2019.02.038

Bhaskaran, S. R., & Gilbert, S. M. (2015). Implications of Channel Structure and Operational Mode Upon a Manufacturer's Durability Choice. *Production and Operations Management*, *24*(7), 1071–1085. https://doi.org/10.1111/POMS.12335

Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production*, *65*, 42–56. https://doi.org/10.1016/J.JCLEPRO.2013.11.039

Byard, D. J., Woern, A. L., Oakley, R. B., Fiedler, M. J., Snabes, S. L., & Pearce, J. M. (2019). Green fab lab applications of large-area waste polymer-based additive manufacturing. *Additive Manufacturing*, *27*, 515–525. https://doi.org/10.1016/J.ADDMA.2019.03.006

Cainelli, G., D'Amato, A., & Mazzanti, M. (2015). Adoption of waste-reducing technology in manufacturing: Regional factors and policy issues. *Resource and Energy Economics*, *39*, 53–67. https://doi.org/10.1016/J.RESENEECO.2014.11.004

Centobelli, P., Cerchione, R., Chiaroni, D., del Vecchio, P., & Urbinati, A. (2020). Designing business models in circular economy: A systematic literature review and research agenda. *Business Strategy and the Environment*, *29*(4), 1734–1749. https://doi.org/10.1002/BSE.2466

Chertow, M. R. (2000). Industrial symbiosis: Literature and taxonomy. *Annual Review of Energy and the Environment*, *25*, 313–337. https://doi.org/10.1146/ANNUREV.ENERGY.25.1.313

Chhimwal, M., Agrawal, S., & Kumar, G. (2021). Challenges in the implementation of circular economy in manufacturing industry. *Journal of Modelling in Management*. https://doi.org/10.1108/JM2-07-2020-0194

Clemon, L. M., & Zohdi, T. I. (2018). On the tolerable limits of granulated recycled material additives to maintain structural integrity. *Construction and Building Materials*, *167*, 846–852. https://doi.org/10.1016/J.CONBUILDMAT.2018.02.099

Conticelli, E., & Tondelli, S. (2014). Eco-Industrial Parks and Sustainable Spatial Planning: A Possible Contradiction? *Administrative Sciences*, *4*(3), 331–349. https://doi.org/10.3390/admsci4030331

Dahmani, N., Benhida, K., Belhadi, A., Kamble, S., Elfezazi, S., & Jauhar, S. K. (2021). Smart circular product design strategies towards eco-effective production systems: A lean eco-design industry 4.0 framework. *Journal of Cleaner Production*, *320*, 128847. https://doi.org/10.1016/J.JCLEPRO.2021.128847

de Jesus, A., & Mendonça, S. (2018). Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy. *Ecological Economics*, *145*, 75–89. https://doi.org/10.1016/J.ECOLECON.2017.08.001

Demirel, P., & Kesidou, E. (2011). Stimulating different types of eco-innovation in the UK: Government policies and firm motivations. *Ecological Economics*, *70*(8), 1546–1557. https://doi.org/10.1016/j.ecolecon.2011.03.019

Despeisse, M., Baumers, M., Brown, P., Charnley, F., Ford, S. J., Garmulewicz, A., Knowles, S., Minshall, T. H. W., Mortara, L., Reed-Tsochas, F. P., & Rowley, J. (2017). Unlocking value for a circular economy through 3D printing: A research agenda. *Technological Forecasting and Social Change*, *115*, 75–84. https://doi.org/10.1016/J.TECHFORE.2016.09.021

Do, Q., Ramudhin, A., Colicchia, C., Creazza, A., & Li, D. (2021). A systematic review of research on food loss and waste prevention and management for the circular economy. *International Journal of Production Economics*, *239*, 108209. https://doi.org/10.1016/J.IJPE.2021.108209

Fisher, O., Watson, N., Porcu, L., Bacon, D., Rigley, M., & Gomes, R. L. (2018). Cloud manufacturing as a sustainable process manufacturing route. *Journal of Manufacturing Systems*, *47*, 53–68. https://doi.org/10.1016/J.JMSY.2018.03.005

Fonseca, L. M., Domingues, J. P., Pereira, M. T., Martins, F. F., & Zimon, D. (2018). Assessment of circular economy within Portuguese organizations. *Sustainability (Switzerland)*, *10*(7), 1–24. https://doi.org/10.3390/su10072521

Franklin-Johnson, E., Figge, F., & Canning, L. (2016). Resource duration as a managerial indicator for Circular Economy performance. *Journal of Cleaner Production*, *133*, 589–598. https://doi.org/10.1016/J.JCLEPRO.2016.05.023

COM(2016) 736 final, COM(2016) 739 final 1 (2016). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016DC0739&from=ES

Fu, Y. (2019). *Understanding the adoption of sustainable process technologies in the manufacturing industry*. Radboud University.

Garmulewicz, A., Holweg, M., Veldhuis, H., & Yang, A. (2018). Disruptive Technology as an Enabler of the Circular Economy: What Potential Does 3D Printing Hold? *California Management Review*, *60*(3), 112–132. https://doi.org/10.1177/0008125617752695

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/J.JCLEPRO.2016.12.048

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/J.JCLEPRO.2015.09.007

Giurco, D., Littleboy, A., Boyle, T., Fyfe, J., & White, S. (2014). Circular economy: Questions for responsible minerals, additive manufacturing and recycling of metals. *Resources*, *3*(2), 432–453. https://doi.org/10.3390/RESOURCES3020432

Govindan, K., & Hasanagic, M. (2018). A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. *International Journal of Production Research*, *56*(1–2), 278–311. https://doi.org/10.1080/00207543.2017.1402141

Hartley, K., Roosendaal, J., & Kirchherr, J. (2022). Barriers to the circular economy: The case of the Dutch technical and interior textiles industries. *Journal of Industrial Ecology*, *26*, 477–490. https://doi.org/10.1111/JIEC.13196

Helmer Pedersen, T., & Conti, F. (2017). Improving the circular economy via hydrothermal processing of high-density waste plastics. *Waste Management*, *68*, 24–31. https://doi.org/10.1016/J.WASMAN.2017.06.002

Ilić, M., & Nikolić, M. (2016). Drivers for development of circular economy – A case study of Serbia. *Habitat International*, *56*, 191–200. https://doi.org/10.1016/J.HABITATINT.2016.06.003

Jaeger, B., & Upadhyay, A. (2020). Understanding barriers to circular economy: cases from the manufacturing industry. *Journal of Enterprise Information Management*, *33*(4), 729–745. https://doi.org/10.1108/JEIM-02-2019-0047

Jarzabkowski, P., & Spee, A. P. (2009). Strategy-as-practice: A review and future directions for the field. *International Journal of Management Reviews*, *11*(1), 69–95. https://doi.org/10.1111/J.1468-2370.2008.00250.X

Jawahir, I. S., & Bradley, R. (2016). Technological Elements of Circular Economy and the Principles of 6R-Based Closed-loop Material Flow in Sustainable Manufacturing. *Procedia CIRP*, *40*, 103–108. https://doi.org/10.1016/J.PROCIR.2016.01.067

Jensen, P. B., Laursen, L. N., & Haase, L. M. (2021). Barriers to product longevity: A review of business, product development and user perspectives. *Journal of Cleaner Production*, *313*, 127951. https://doi.org/10.1016/J.JCLEPRO.2021.127951

Jørgensen, U. (2012). Mapping and navigating transitions—The multi-level perspective compared with arenas of development. *Research Policy*, *41*(6), 996–1010. https://doi.org/10.1016/J.RESPOL.2012.03.001

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). *Ecological Economics*, *150*, 264–272. https://doi.org/10.1016/J.ECOLECON.2018.04.028

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*, *143*, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, *175*, 544–552. https://doi.org/10.1016/J.JCLEPRO.2017.12.111

Kulczycka, J., Kowalski, Z., Smol, M., & Wirth, H. (2016). Evaluation of the recovery of Rare Earth Elements (REE) from phosphogypsum waste – case study of the WIZÓW Chemical Plant (Poland). *Journal of Cleaner Production*, *113*, 345–354. https://doi.org/10.1016/J.JCLEPRO.2015.11.039

Lahtela, V., & Kärki, T. (2018). Mechanical sorting processing of waste material before composite manufacturing - A review. *Journal of Engineering Science and Technology Review*, *11*(6), 35–46. https://doi.org/10.25103/JESTR.116.06

Lay, G., & Maloca, S. (2004). Dokumentation der Umfrage Innovationen in der Produktion 2003. In *Arbeitspaper des Fraunhofer ISI*.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, 36–51. https://doi.org/10.1016/J.JCLEPRO.2015.12.042

Longest, K. C., & Vaisey, S. (2008). fuzzy: A program for performing qualitative comparative analyses (QCA) in Stata. *The Stata Journal*, *8*(1), 79–104. https://doi.org/10.1177/1536867X0800800106

Lowe, E. A., Moran, S. R., & Holmes, D. B. (1996). *Fieldbook for the Development of Eco-Industrial Parks*. Indigo Development for US-EPA. https://p2infohouse.org/ref/10/09932.pdf

Marrucci, L., Daddi, T., & Iraldo, F. (2019). The integration of circular economy with sustainable consumption and production tools: Systematic review and future research agenda. *Journal of Cleaner Production*, *240*, 118268. https://doi.org/10.1016/j.jclepro.2019.118268

Marrucci, L., Daddi, T., & Iraldo, F. (2021). The contribution of green human resource management to the circular economy and performance of environmental certified organisations. *Journal of Cleaner Production*, *319*, 128859. https://doi.org/10.1016/J.JCLEPRO.2021.128859

Meyer, A. D., Tsui, A. S., & Hinings, C. R. (1993). Configurational approaches to organizational analysis. *Academy of Management Journal*, *36*(6), 1175–1195. www.jstor.org/stable/256809

Minunno, R., O'Grady, T., Morrison, G. M., Gruner, R. L., & Colling, M. (2018). Strategies for Applying the Circular Economy to Prefabricated Buildings. *Buildings*, *8*(9), 125. https://doi.org/10.3390/BUILDINGS8090125

Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M., & Paul, S. K. (2018). Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. *Journal of Cleaner Production*, *174*, 1366–1380. https://doi.org/10.1016/j.jclepro.2017.11.063

Moraga, G., Huysveld, S., de Meester, S., & Dewulf, J. (2022). Resource efficiency indicators to assess circular economy strategies: A case study on four materials in laptops. *Resources, Conservation and Recycling*, *178*. https://doi.org/10.1016/J.RESCONREC.2021.106099

Ragin, C. C. (2006). Set Relations in Social Research: Evaluating Their Consistency and Coverage. *Political Analysis*, *14*(3), 291–310. https://doi.org/10.1093/PAN/MPJ019

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation and Recycling*, *135*, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

Reuter, M. A. (2016). Digitalizing the Circular Economy: Circular Economy Engineering Defined by the Metallurgical Internet of Things. *Metallurgical and Materials Transactions B: Process Metallurgy and Materials Processing Science*, *47*(6), 3194–3220. https://doi.org/10.1007/S11663-016-0735-5

Rodríguez-Antón, J. M., Rubio-Andrada, L., Celemín-Pedroche, M. S., & Ruíz-Peñalver, S. M. (2022). From the circular economy to the sustainable development goals in the European Union: an empirical comparison. *International Environmental Agreements: Politics, Law and Economics*, *22*(1), 67–95. https://doi.org/10.1007/S10784-021-09553-4

Roig-Tierno, N., Gonzalez-Cruz, T. F., & Llopis-Martinez, J. (2017). An overview of qualitative comparative analysis: A bibliometric analysis. *Journal of Innovation & Knowledge*, *2*(1), 15–23. https://doi.org/10.1016/J.JIK.2016.12.002

Russell, J., & Nasr, N. (2020). Value-Retention Processes within the Circular Economy. In *Remanufacturing in the Circular Economy: Operations, Engineering and Logistics* (pp. 1–29). Scrivener Publishing LLC. https://doi.org/10.1002/9781119664383

Scarpellini, S., & Romeo, L. M. (1999). Policies for the setting up of alternative energy systems in European SMEs: a case study. *Energy Conversion and Management*, *40*(15–16), 1661–1668. https://doi.org/10.1016/S0196-8904(99)00059-X

Segura-Salazar, J., Lima, F. M., & Tavares, L. M. (2019). Life Cycle Assessment in the minerals industry: Current practice, harmonization efforts, and potential improvement through the integration with process simulation. *Journal of Cleaner Production*, *232*, 174–192. https://doi.org/10.1016/J.JCLEPRO.2019.05.318

Shevchenko, T., & Kronenberg, J. (2020). Management of material and product circularity potential as an approach to operationalise circular economy. *Progress in Industrial Ecology*, *14*(1), 30–57. https://doi.org/10.1504/PIE.2020.105193

Shi, H., Peng, S. Z., Liu, Y., & Zhong, P. (2008). Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. *Journal of Cleaner Production*, *16*, 842–852. https://doi.org/10.1016/j.jclepro.2007.05.002

Siemieniuch, C. E., Sinclair, M. A., & Henshaw, M. J. C. (2015). Global drivers, sustainable manufacturing and systems ergonomics. *Applied Ergonomics*, *51*, 104–119. https://doi.org/10.1016/J.APERGO.2015.04.018

Sihvonen, S., & Partanen, J. (2016). Implementing environmental considerations within product development practices: a survey on employees' perspectives. *Journal of Cleaner Production*, *125*, 189–203. https://doi.org/10.1016/J.JCLEPRO.2016.03.023

Smol, M., Kulczycka, J., Henclik, A., Gorazda, K., & Wzorek, Z. (2015). The possible use of sewage sludge ash (SSA) in the construction industry as a way towards a circular economy. *Journal of Cleaner Production*, *95*, 45–54. https://doi.org/10.1016/J.JCLEPRO.2015.02.051

Sousa-Zomer, T. T., Magalhães, L., Zancul, E., Campos, L. M. S., & Cauchick-Miguel, P. A. (2018). Cleaner production as an antecedent for circular economy paradigm shift at the micro-level: Evidence from a home appliance manufacturer. *Journal of Cleaner Production*, *185*, 740–748. https://doi.org/10.1016/j.jclepro.2018.03.006

Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, *42*, 215–227. https://doi.org/10.1016/J.JCLEPRO.2012.11.020

Tucker, N. (2017). Clean production. In *Green Composites: Waste and Nature-based Materials for a Sustainable Future: Second Edition: Vol. (Second Edition)* (pp. 95–121). Elsevier Inc. https://doi.org/10.1016/B978-0-08-100783-9.00005-8

Turken, N., Cannataro, V., Geda, A., & Dixit, A. (2020). Nature inspired supply chain solutions: definitions, analogies, and future research directions. *International Journal of Production Research*, *58*(15), 4689–4715. https://doi.org/10.1080/00207543.2020.1778206

Ünal, E., Urbinati, A., & Chiaroni, D. (2019). Managerial practices for designing circular economy business models: The case of an Italian SME in the office supply industry. *Journal of Manufacturing Technology Management*, *30*(3), 561–589. https://doi.org/10.1108/JMTM-02-2018-0061

Witjes, S., & Lozano, R. (2016). Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resources, Conservation and Recycling*, *112*, 37–44. https://doi.org/10.1016/j.resconrec.2016.04.015

Yu, C., Davis, C., & Dijkema, G. P. J. (2013). Understanding the evolution of industrial symbiosis research: A bibliometric and network analysis (1997-2012). *Journal of Industrial Ecology*, *18*(2), 280–293. https://doi.org/10.1111/JIEC.12073

Appendix 1 – Table 1

Table 1. Technological and managerial CE practices suggested in CE literature.

CE practices	Description	References	Dimensions	
			Technology	Managerial
Recycling technologies	To recycle metals and recover resources	(Alvarez-de-los-Mozos & Renteria, 2017; Bendikiene et al., 2019; Kulczycka et al., 2016; Smol et al., 2015)	X	x
Additive manufacturing	To facilitate resource circularity at products end-of-life. This technology is proved to be energy and cost-efficient with respect to traditional production, but it can be adopted only for small-scale production	(Byard et al., 2019; Clemon & Zohdi, 2018; Despeisse et al., 2017; Garmulewicz et al., 2018; Giurco et al., 2014)	X	
Cleaner and green technologies	To improve functional efficiency but are also considered more sustainable in terms of lesser pollution and resource consumption	(Bhandari et al., 2019; Shi et al., 2008)	X	
Lean design – Eco-design	To maximise customer value and reduce waste at all stages of the product life cycle by optimising product design.	(Dahmani et al., 2021)	X	x
Waste recovery technologies	To dismantle waste generated by manufacturers by also handling hazardous waste	(Alvarez-de-los-Mozos & Renteria, 2017; Helmer Pedersen & Conti, 2017; Lahtela & Kärki, 2018)	X	
Remanufacturing technologies	Technical equipment and technologies are required to develop products in different ways if they are to be remanufactured	(Alvarez-de-los-Mozos & Renteria, 2017)	X	x
Cloud manufacturing	To promote resource recovery, recycling and waste minimization giving greater flexibility to systems	(Fisher et al., 2018)	X	
Tracking technologies	Measurable data to measure the environmental performance in regards of the initiatives by implementing CE	(Minunno et al., 2018)	X	
Lean manufacturing	Organisational learning positively impacts lean product development, zero waste practices and lean manufacturing practices and zero waste practices.	(Agyabeng-Mensah et al. 2021)	X	x
Product design & clean production	The manufacturers investigated focus mostly on recycling and waste reduction. These policies have low or very low CE effect	(Jaeger & Upadhyay, 2020; Sousa-Zomer et al., 2018)	X	x
Secondary materials technologies	Material flows, technology policy, and facilities—in order to assess 3D printing's viability as an enabler of a circular economy at the local level	(Garmulewicz et al., 2018)	X	x

CE practices	Description	References	Dimensions: Technology	Dimensions: Managerial
Effective communication	Establishment of effective communication, Support of all partners to develop awareness and new skills	(Ünal et al., 2018)		X
Support and commitment	Support and commitment from top management is an essential link to enhancing and introducing CE practices	(Moktadir et al., 2018; Siemieniuch et al., 2015; Sihvonen & Partanen, 2016)		X
Leadership and visionary thinking	To implement circular economy in the supply chain, the firm should have visionary thinking and the same should be integrated with the firm's overall motto. However, this kind of thinking involves technical creativity, on-site thinking and so on	(Jawahir & Bradley, 2016)		X
Green Human Resources Management	GHRM practices, i.e., recruiting and involvement, are effective in increasing circularity in organisations. To Give incentives to increase employment rates in a circular economy	(Lieder & Rashid, 2016; Marrucci et al., 2021)		X
Training in regards of CE in supply chain	Not only university education is important, but also virtual education is essential to educate and prepare the workforce for the new shift in the manufacturing industry toward the circular economy	(Ilić & Nikolić, 2016; Jawahir & Bradley, 2016; Lieder & Rashid, 2016; Su et al., 2013)		X
Education on recycling, remanufacturing and reuse	Sustainable education serves as a tool to educate and increase awareness among the actors involved in supply chain. It assists top-level managers to know about the long-term importance of implementing cleaner production. In addition, this practice can bring change in the social thinking towards the circular economy	(Ilić & Nikolić, 2016; Jawahir & Bradley, 2016; Lieder & Rashid, 2016; Su et al., 2013)		X
Performance indicators and Environmental Management Systems	Measuring the enterprises' implementation of circular economy and how they are doing, so it can be done better. It should be able to evaluate how much the products affect the environment, and it must be known to the consumer	(Fonseca et al., 2018; Franklin-Johnson et al., 2016; Marrucci et al., 2019; Reuter, 2016)		X
Industrial symbiosis	Collaboration and cooperation with other industries and industrial parks can improve the effectiveness of circular economy implementation through sharing economy to make it possible to reuse/recycle/ remanufacture	(Ghisellini et al., 2016)		X

Note: capital X indicates main focus, small x minor focus.

Appendix 2 –

Table 5. Overview of Outcome and CE practices suggested in CE literature and congruent EMS variables

Practices type	EMS variables	and labels	Stage of production	Range	Adopted (%)
Outcome of CE	CE	Number of technological and managerial practices applied		0 to 1	99.3 (mean: 4.81, sd: 2.33)
Technology practices					
Eco-design	ProdEnvInno:	New or improved products also lead to an improved environmental impact when using or disposing of them (health, energy, retrofit, lifetime, pollution, recycling)	1	0/1	31.6
Product design	VirReality:	Virtual Reality or simulation for product design or product development (e.g., FEM, Digital Prototyping, computer models)	1	0/1	14.2
	3Dprototype:	3D printing technologies for prototyping (prototypes, demonstration models, 0 series)	1	0/1	16.3
Lean design	Make2Order:	Manufacturing - Upon receipt of customer's order, i.e., made-to-order	1	0/1	33.7
	Assemble2Order:	Manufacturing - Final assembly of the product is carried out upon receipt of customer's order	1	0/1	45.5
	ProdPlanning:	Software for production planning and scheduling (e.g., ERP system)	1	0/1	67.0
Secondary materials	SecMaterials:	Secondary metals or plastics used in your factor for manufacturing of your main product	1	0/1	32.3
Clean production	SecMatTech:	Integrate specific technologies into your manufacturing process for that use secondary materials or plastics	2	0/1	9.4
	CleanProdData:	Machines or systems in your production that automatically store operating data - optimizing, maintenance, resource utilization, productivity	2	0/1	44.8
Additive Manufacturing	3Dprint:	3D printing technologies for manufacturing of products, components and forms, tools etc.)	2	0/1	8.7
Cloud manufacturing	DigExchange:	Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI)	2	0/1	26.7
	RealtimeControl:	Near real-time production control system (e.g., Systems of centralized operating and machine data acquisition, MES	2	0/1	25.0

Practices type	EMS variables	and labels	Stage of production	Range	Adopted (%)
Remanufacturing	Modernization:	Product-related services do you offer your customers - Revamping or modernization	3	0/1	21.2
	Maintenance:	product-related services do you offer your customers - Maintenance and repair	3	0/1	35.4
Recycling	SusWater:	Technologies for recycling and re-use of water (e.g., water recirculating system)	3	0/1	20.8
	SusEnergy:	Technologies to recuperate kinetic and process energy (e.g., waste heat recovery, energy storage)	3	0/1	17.4
Waste recover	TakeBack:	Product-related services do you offer your customers - Take-back services (e.g., recycling, disposal, taking back)	3	0/1	19.1
Tracking technologies	PLCsystems:	Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	3	0/1	11.5
Managerial practices					
Knowledge	RD:	Research and development (R&D) or award R&D contracts to external partners in 2017	1,2,3	0/1	47.9
Training and Skills development	JobTraining:	Training on the job (e.g., job rotation, organised exchange of experiences with colleagues, TWI)	1,2,3	0/1	57.6
Production policy	WorkInstruction:	Standardized and detailed work instructions (e.g., standard operation procedures SOP, MOST)	2	0/1	47.6
Human resources	StaffLoyalty:	Instruments to promote staff loyalty (e.g., attractively designed responsibilities, offering learning opportunities, flexible working house, childcare)	2	0/1	58.0
Information	DisplayBoards:	Display boards in production to illustrate work processes and work status (e.g., Visual Management)	1,2	0/1	45.8
Quality Process	QualityMeasures:	Methods of assuring quality in production (e.g., CIP, TQM, SixSigma, preventive maintenance)	2	0/1	55.2
Manual operation	IntegrationTasks:	Integration of tasks (planning, operating, or controlling functions with the machine operator)	3	0/1	44.4
Production Cooperation	CollProduction:	Production co-operation (e.g., for capacity compensation or for joint utilization of machinery)	2	0/1	30.2
EMS & Government support and legality	CertifiedEnvMS:	Certified environmental management system (e.g., EN ISO 14001)	1,2	0/1	29.9

Chapter 7. Discussion and Conclusions

"And what I believe does a great deal of good is if one doesn't work absolutely alone, because the work inevitably absorbs one, but one doesn't become lost in that absorption because each advises the other, can keep the other on the right path"
Vincent Van Gogh

7.1 Discussion and conclusions

The first dissertation (Chapter 3) seeks to answer the first specific research question, which asks whether 'Is there a relationship between companies that adopt more circularity practices and those that have implemented an Environmental Management System?'. Through a survey of 85 Spanish manufacturing companies, it was observed that the implementation of an EMS has a positive relationship with circularity. The analysed companies adopted a higher number of CE practices, thus corroborating what Fonseca et al. (2018) mentioned, who noted that EMS certification and strategic choice to improve environmental performance are related to higher levels of CE intensity. This study also explored the model of the fields of action of CE (Prieto-Sandoval et al., 2018) and their relationship (*Take*, *Make*, *Distribute*, *Use*, *Recover*) with companies that have an EMS. It was found that only in the *Make* field does the adoption of EMS favourably influence the taking of circular initiatives, such as in the development of better technological practices and design oriented to the extension of the product's useful life.

Additionally, and to contrast what is mentioned in the literature by DeBoer et al. (2017), Marrucci et al. (2022) and Niesten & Jolink (2015) on the need to analyse green clusters or cooperation and partnership between companies for circularity, the field of Industrial Symbiosis was added to Prieto-Sandoval et al. (2018) 's model. Although it can be a cross-cutting aspect in the different fields of action, it was observed separately in this study. The results indicated no relationship between the implementation of an EMS and circular initiatives in the establishment of cross-industry synergies. Therefore, strategies that act as connectors between companies considering circularity and sustainability in their environmental policies could be promoted.

The second dissertation (Chapter 4) sought to answer the second specific question: What is the relationship between reporting and communication of environmental performance and the adoption of CE by companies? This study used EMAS public statements as an instrument, mainly to take into consideration two of the most mentioned aspects in the literature review: first, the need to expand research on how regulation and public policies intervene in the adoption of circularity practices in companies (Fonseca et al., 2018; Marrucci & Daddi, 2021), and second, the role of EMS verification and certification (Dagiliene et al., 2020).

The environmental declarations of 31 sites belonging to the industrial and manufacturing sector in Catalonia, Spain, were analysed, and the same conceptual framework of the previous study (Chapter 3) on fields of action was maintained (Prieto-Sandoval et al., 2018). Several relevant results were reached in the analysis of the statements. First, 23 CE-related practices were identified within the statements. Second, most of the practices mentioned are mainly related to the *Take*, *Make* and *Recover* fields, leaving aside the *Distribute* and *Use* fields. Third, the most frequently reported practices related to natural resource consumption, emission reduction and waste management. However, practices concerning product life cycle and value retention options are scarcely mentioned.

Applying a CE-based production model means much more than reducing waste through recycling. It requires more outstanding efforts in implementing strategies focused on short and medium-cycle loops (Reike et al., 2018; Vermeulen et al., 2019). Such as reducing the consumption of raw materials, designing environmentally friendly products that can be quickly recovered and reused, extending the lifetime of products through proper maintenance, using recyclable materials in products and taking actions to recover raw materials from waste streams.

On the other hand, we analysed whether there was a relationship between circularity practices by applying the Phi correlation coefficient test. Found that eco-design was the practice with the highest correlation with other CE practices, such as returning materials to the factory after use, extending the product life cycle, reintegrating waste into the internal production process and using recycled and recirculated raw materials. Finally, it was found that, although in very few statements, the term 'Circular Economy' is directly mentioned, there is a report of linked practices. EMAS has as its strong points the transparency and communication of the commitments, policies and actions undertaken by companies in the field of circularity and sustainability by requiring in its requirements the submission of annual reports and the periodic verification of the system. However, if the potential of the quantitative information reported in the statements is to be fully exploited, it is necessary to standardise the presentation of data. Thus, to facilitate interpretation and comparison between firms by sector or region and using CE indicators.

The third dissertation (Chapter 5) was developed by adopting the methodology of Content Analysis of EMAS environmental statements used in the previous dissertation (Chapter 4), extending the study to the whole Spanish territory and including large companies. This consideration allowed us to contribute to one of the gaps mentioned in the literature review by Jain et al. (2020). The exploration of the role of institutional pressures on the adoption of circularity. Furthermore, more specifically, whether the reporting of circularity practices differs according to company size. In our study, no significant differences were found between the two groups, so we can conclude that there is no mimetic influence between large and SME firms in reporting circularity practices.

Considering the European Commission's commitment to CE (European Commission, 2017; COM(2015) 614 Final, 2015; COM(2019) 640 Final, 2019), the coercive influence was analysed based on the environmental statements of companies that had implemented an EMS regulated by the same European Commission. To this end, the possible relationship between companies mentioning the term 'Circular Economy' in their environmental declarations and those reporting a higher number of CE practices was explored. Using Kendall's Tau-b coefficient, statistical analysis showed a correlation between a higher number of reported CE practices and the mention of 'Circular Economy' in environmental statements. This result also suggests that companies aware of the CE model are more committed to implementing more actions aligned with circularity principles. Regarding circularity practices, in this study, compared to the previous study carried out in Catalonia, only 17 practices were included. The number of practices to be considered was reduced by implementing the R'Imperatives.

To answer the specific research question, *Does environmental performance reporting allow measuring the implementation of CE within manufacturing firms?*, the study indicated that the information contained in the declarations is not sufficiently comprehensive, nor is it based on scalable and comparable quantitative data. In particular, the study analysed whether any measurement is expressed in percentages or units, finding only three quantified practices in some declarations: 'Quantification of the number of raw materials from sustainable sources', 'Quantification of the use of renewable energy' and 'Quantification of waste recovery/reintegration'. These results contradict the EC's 2017 statement that the six core indicators that environmental declarations should contain are valid for assessing circularity at the micro-level (European Commission, 2017).

The fourth dissertation (Chapter 6) departs from the focus on environmental reporting and statements covering other aspects: *Is there a particular combination of organisational and technological practices that drive CE within manufacturing companies?* What role do EMS play in such a configuration, and what is the role of EMS as an organisational practice in itself and its relationship to other organisational and technological practices focused on circularity? This study addresses EMS as an organisational practice in its own right, and its relationship to other organisational and technological practices focused on circularity. First, following a literature review focused on this area, ten organisational and eleven technological practices aimed at promoting CE principles in manufacturing firms were identified within the broad spectrum of business practices. A sample of 288 Dutch and Spanish companies that participated in the European Manufacturing Survey was taken to test the hypothesis of the existence of specific configurations of practices that promote the CE.

After applying the Qualitative Comparative Analysis methodology, possible configurations for the production stages (Pre-production, Production and Value Retention) were explored. The findings indicated eleven (11) configurations for the Pre-production stage, four (4) configurations for the Production stage and ten (10) configurations for the Value Retention stage. Despite the high levels of overall consistency, there are multiple consistent pathways by which configurations are associated with more CE, i.e. manufacturing companies have yet to find a standard configuration of technologies and management practices that prevail at each stage of the production process. However, the combinations presented for each production stage are a good starting point for adopting CE in manufacturing and reveal which practices require more emphasis in their application. The study also corroborated two of the critical organisational practices most often mentioned in the literature: *employee training on CE* and related technologies and the practice of *Knowledge*, particularly on the application of circularity processes within manufacturing.

Within the set of configurations, we found that EMS are most relevant in the pre-production stages, with presence in all eleven configurations and presence in tree out of four configurations in the production stage. This result indicates that in its current form, EMS need more tools to support the value retention stages in the manufacturing industry. However, it does have a preponderant role in the initial and intermediate stages. On the other hand, the application of an EMS could enhance the use and adaptation of other organisational CE practices such as *Information*: internal and external communication of environmental policies, environmental performance reports and status of progress on the objectives set; *Training and Skill development*: training and education in soft and hard skills that facilitate the transformation of processes and products to be more circular; *Knowledge*: Detection of opportunities to incentivise innovation and R&D processes; *Quality process*: improvements in the efficiency of materials and products; *Human Resources*: staff awareness of circularity; *Production cooperation*: the creation of green clusters that incentivise the connection between companies to detect opportunities; and *Government Support and legality*: in the case of EMAS that can introduce CE concepts in registered organisations.

The following are the contributions and implications of this dissertation:

Theorical Contribution

- The analysis of the reporting of circularity practices in environmental statements from institutional theory, mainly from mimetic and coercive influence.
- To the contradictions and conflicts in the literature related to circularity principles (Cui, 2021; Geissdoerfer et al., 2017; Stumpf et al., 2021), this study seeks to contribute by delineating concepts such as Principles and Strategies for production stages, by

proposing an understanding of the 'When', 'What' and 'How' in the adoption of CE in the manufacturing sector.

- It proposes a conceptual starting point in developing organisational and technological configurations that promote CE in manufacturing companies at different stages of production.

Implications for governments, policy makers and Institutions

- This thesis, through the results obtained, indicated that EMS contribute to making manufacturing companies more circular. However, turning them into efficient tools in the transition requires further efforts from the managing bodies to a legitimate commitment of the companies seeking environmental certification.

- Crucial aspects discussed in the EMS+CE literature, such as communication and reporting of environmental performance and periodic verification of the EMS. In this sense, the European Commission, through the EMAS regulation, could incentivise mechanisms for implementing more EMAS in European companies. Also, by adjusting the EMAS regulation to align it more closely with the circularity objectives set out in the CE: Action Plan (COM(2015) 614 Final, 2015) and the European Green Deal (COM(2019) 640 Final, 2019).

- Finally, this thesis demonstrates the relevant role of public environmental reports coupled with an EMS. Mainly because an environmental report in itself, apart from communicating the results regularly, does not offer the possibilities that an EMS offers. By setting policies in favour of circularity and establishing intra- and inter-organisational commitments under management's leadership (Marrucci et al., 2021a), as well as setting guidelines for continuous improvement in the established actions. Also, indicating that the annual verification from the EMS could reduce one of the most commented problems in the literature: environmental certification for "greenwaching" (Scarpellini, Valero-Gil, et al., 2020). That is, reducing certification for marketing or promotional reasons and promoting those aspects of the EMS that encourage firms to assume a legitimate commitment to the continuous improvement of environmental performance.

Implications for businesses

- It shows the interest and actions of companies to improve their environmental performance in the long loop with practices such as recycling and waste management. However, it points out the importance of delving into the short and medium loops, mainly by adopting practices focused on product life cycle, eco-design and value retention.

- Within the study of particular combinations of practices that drive CE in manufacturing companies, it is noted that two of the essential practices for becoming more circular and facilitating the incorporation of other practices and technologies are the 'Training' of employees in CE and related technologies and the practice of 'Knowledge', particularly in the application of circularity processes within manufacturing.

Implications for consumers

- Although this thesis did not analyse the role of consumers directly, according to the results obtained, it is suggested that consumers and users can play a more proactive role by requesting environmental management certificates and, even more, by demanding periodic and publicly available environmental reports to know the environmental performance of companies and their genuine commitment to the efficient use of resources, as well as the achievement of goals and objectives focused on Sustainability and Circular Economy.

7.2 Limitations and future research directions

The essays that led to the results and conclusions of this study found some limitations, which need to be addressed with further research in the future:

The first essay (Chapter 3) has the limitation of a low response rate; this is mainly due to the complexity of the European Manufacturing survey, which has been reflected in a reduction in the response rate over the years. Therefore, we invite extending the sample in future studies to contrast the results obtained and include other aspects such as company size and sector.

The second and third essays (Chapters 4 and 5) were carried out only with EMAS environmental declarations as an instrument of analysis, so other instruments, including other EMSs such as ISO14001, or even environmental reports independent of an EMS, should be used to compare the results. Additionally, it would be convenient to extend the analysis to primary sources such as interviews or surveys considering the CE practices that manufacturing companies implement. It is also suggested that longitudinal studies be carried out to analyse the impact of the growing debate on climate change and the broader dissemination of policies in favour of sustainable production and consumption on the behaviour of companies.

The fourth and last essay (Chapter 6) is limited by the fact that it was conducted on a survey more focused on innovation than on circularity, which is why future studies are invited to use instruments more focused on CE and sustainable production. It is also interesting to analyse causality between organisational practices and technologies in future research, as this study was only observed under the configurational prism.

Generally, this doctoral thesis was developed during the COVID-19 juncture, which required some changes in the research plan and the impossibility of carrying out a case study that would allow us to observe all the analysed aspects of previous studies of EMSs as facilitators of CE in companies with a high intensity of circularity practices or whose productive system was based on regenerative and circular models. We leave this aspect as a suggestion for future lines of research, which in turn would make it possible to validate or corroborate the hypotheses put forward in this thesis. Finally, we invite to consider in future studies the critical aspects of the evolution of production systems and their impact not only at the environmental level but also at the social and economic level.

Figure 8 shows a graphical summary of the results of the thesis.

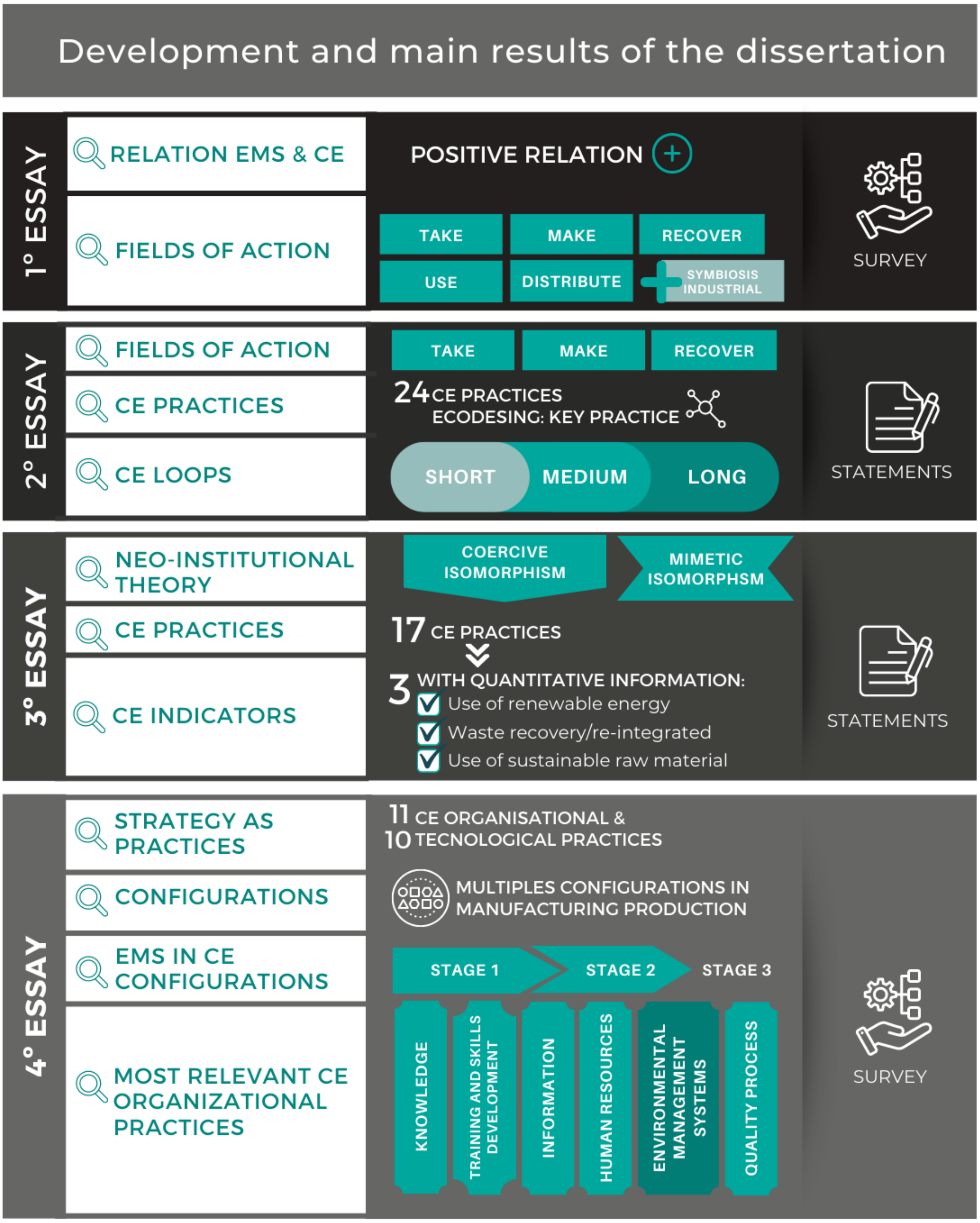

Figure 8. Development and main results of the dissertation. Own elaboration

General References

Ball, P., & Lunt, P. (2019). Enablers for Improving Environmental Performance of Manufacturing Operations. *IEEE Transactions on Engineering Management*, *66*(4), 663–676. https://doi.org/10.1109/TEM.2018.2871613

Barwise, J. (1998). *Environmental Management Systems: A Guide for the HE Sector*.

Bleischwitz, R., Yang, M., Huang, B., XU, X., Zhou, J., McDowall, W., Andrews-Speed, P., Liu, Z., & Yong, G. (2022). The circular economy in China: Achievements, challenges and potential implications for decarbonisation. *Resources, Conservation and Recycling*, *183*. https://doi.org/10.1016/J.RESCONREC.2022.106350

Brundtland, G. H., Khalid, M., Agnelli, S., Al-Athel, S. A., Chidzero, B., Fadika, L. M., Hauff, V., Lang, I., Ma, S., Botero, M. M., & Singh, N. (1987). Our Common Future: Report of the World Commission on Environment and Development. In *1987*. Oxford University Press. http://www.un-documents.net/ocf-02.htm

Chick, N., & Meleis, A. I. (1986). Transitions: A nursing concern. In *Nursing research methodology* (pp. 237–257). Aspen Publication. https://repository.upenn.edu/nrs/9

Regulation (EU) 2017/1505, Official Journal of the European Union, L222 (2017).

Cui, M. (2021). Key Concepts and Terminology. *An Introduction to Circular Economy*, 17–34. https://doi.org/10.1007/978-981-15-8510-4_2

Dagiliene, L., Frendzel, M., Sutiene, K., & Wnuk-Pel, T. (2020). Wise managers think about circular economy, wiser report and analyze it. Research of environmental reporting practices in EU manufacturing companies. *Journal of Cleaner Production*, *274*, 121968. https://doi.org/10.1016/J.JCLEPRO.2020.121968

DeBoer, J., Panwar, R., & Rivera, J. (2017). Toward A Place-Based Understanding of Business Sustainability: The Role of Green Competitors and Green Locales in Firms' Voluntary Environmental Engagement. *Business Strategy and the Environment*, *26*(7), 940–955. https://doi.org/10.1002/BSE.1957

de Villiers, C., & Alexander, D. (2014). The institutionalisation of corporate social responsibility reporting. *British Accounting Review*, *46*(2), 198–212.

Ellen Macarthur Foundation. (2015). Towards a Circular Economy: Business Rationale for an Accelerated Transition. *Ellen MacArthur Foundation*, 20.

European Commission. (2017). Moving towards a circular economy with EMAS. In *Circular Economy Strategy. Roadmap*. https://doi.org/10.2779/463312

Fonseca, L., Domingues, J., Pereira, M., Martins, F., & Zimon, D. (2018). Assessment of Circular Economy within Portuguese Organizations. *Sustainability*, *10*(7), 2521. https://doi.org/10.3390/su10072521

COM(2015) 614 final, Pub. L. No. COM(2015) 614 final (2015).

COM(2019) 640 final, 53 European Commission 24 (2019). https://doi.org/10.1017/CBO9781107415324.004

Gall, M., Gall, J. P., & Borg, W. R. (1996). *Education research: An introduction*.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/J.JCLEPRO.2016.12.048

Giménez Leal, Gerusa., & Valls Pasola, Jaume. (2001). *Anàlisi d'escenaris i tendències en l'àmbit de la gestió mediambiental a la indústria catalana*. http://hdl.handle.net/10803/7695

Gorden, M., & Gorden, Ma. (1972). *Environmental management science and politics*.

Gunarathne, N., Wijayasundara, M., Senaratne, S., Kanchana, P. D. K., & Cooray, T. (2021). Uncovering corporate disclosure for a circular economy: An analysis of sustainability and integrated reporting by Sri Lankan companies. *Sustainable Production and Consumption*, *27*, 787–801. https://doi.org/10.1016/J.SPC.2021.02.003

Haller, A., van Staden, C. J., & Landis, C. (2018). Value Added as part of Sustainability Reporting: Reporting on Distributional Fairness or Obfuscation? *Journal of Business Ethics*, *152*(3), 763–781. https://doi.org/10.1007/S10551-016-3338-9

Hart, C. (1998). *Doing a literature review : releasing the social science research imagination*. SAGE Publications.

Jain, N. K., Panda, A., & Choudhary, P. (2020). Institutional pressures and circular economy performance: The role of environmental management system and organizational flexibility in oil and gas sector. *Business Strategy and the Environment*, *29*(8), 3509–3525. https://doi.org/10.1002/BSE.2593

Khan, F., & Ali, Y. (2022). A facilitating framework for a developing country to adopt smart waste management in the context of circular economy. *Environmental Science and Pollution Research*, *29*(18), 26336–26351. https://doi.org/10.1007/S11356-021-17573-5

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232.

Kristensen, H. S., Mosgaard, M. A., & Remmen, A. (2021). Integrating circular principles in environmental management systems. *Journal of Cleaner Production*, *286*, 125485. https://doi.org/10.1016/J.JCLEPRO.2020.125485

Leseure, M. J., Bauer, J., Birdi, K., Neely, A., & Denyer, D. (2004). Adoption of promising practices: a systematic review of the evidence. *International Journal of Management Reviews*, *5–6*(3–4), 169–190. https://doi.org/10.1111/J.1460-8545.2004.00102.X

Marrucci, L., & Daddi, T. (2021). *The contribution of the Eco-Management and Audit Scheme to the environmental performance of manufacturing organisations*. https://doi.org/10.1002/bse.2958

Marrucci, L., Daddi, T., & Iraldo, F. (2019). The integration of circular economy with sustainable consumption and production tools: Systematic review and future research agenda. *Journal of Cleaner Production*, *240*, 118268. https://doi.org/10.1016/J.JCLEPRO.2019.118268

Marrucci, L., Daddi, T., & Iraldo, F. (2021a). The circular economy, environmental performance and environmental management systems: the role of absorptive capacity. *Journal of Knowledge Management*, *26*(8), 2107–2132. https://doi.org/10.1108/JKM-06-2021-0437/FULL/PDF

Marrucci, L., Daddi, T., & Iraldo, F. (2021b). The contribution of green human resource management to the circular economy and performance of environmental certified organisations. *Journal of Cleaner Production*, *319*, 128859. https://doi.org/10.1016/J.JCLEPRO.2021.128859

Marrucci, L., Daddi, T., & Iraldo, F. (2022). Do dynamic capabilities matter? A study on environmental performance and the circular economy in European certified organisations. *Business Strategy and the Environment*, *31*(6), 2641–2657. https://doi.org/10.1002/BSE.2997

Meleis, A. I., Sawyer, L. M., Im, E. O., Messias, D. A. K. H., & Schumacher, K. (2000). Experiencing transitions: An emerging middle-range theory. *Advances in Nursing Science*, *23*(1), 12–28. https://doi.org/10.1097/00012272-200009000-00006

Merli, R., & Preziosi, M. (2018). The EMAS impasse: Factors influencing Italian organizations to withdraw or renew the registration. *Journal of Cleaner Production*, *172*, 4532–4543. https://doi.org/10.1016/j.jclepro.2017.11.031

Murray, A., Skene, K., & Haynes, K. (2015). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics 2015 140:3*, *140*(3), 369–380. https://doi.org/10.1007/S10551-015-2693-2

Niesten, E., & Jolink, A. (2015). The impact of alliance management capabilities on alliance attributes and performance: A literature review. *International Journal of Management Reviews*, *17*(1), 69–100. https://doi.org/10.1111/IJMR.12037

Ociepa-Kubicka, A., Deska, I., & Ociepa, E. (2021). Organizations towards the Evaluation of Environmental Management Tools ISO 14001 and EMAS. *Energies 2021, Vol. 14, Page 4870*, *14*(16), 4870. https://doi.org/10.3390/EN14164870

Regulation (EC) No 1221/2009, Official Journal of the European Union, L342 (2009).

Prieto-Sandoval, V., Ormazabal, M., Jaca, C., & Viles, E. (2018). Key elements in assessing circular economy implementation in small and medium-sized enterprises. *Business Strategy and the Environment*, *27*(8), 1525–1534. https://doi.org/10.1002/bse.2210

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation and Recycling*, *135*, 246–264.

Sariatli, F. (2017). Linear Economy versus Circular Economy: A comparative and analyzer study for optimization of economy for Sustainability. *Visegrad Journal on Bioeconomy and Sustainable Development, 6(1),* 31-34. https://doi.org/10.1515/vjbsd-2017-0005

Scarpellini, S., Marín-Vinuesa, L. M., Aranda-Usón, A., & Portillo-Tarragona, P. (2020). Dynamic capabilities and environmental accounting for the circular economy in businesses. *Sustainability Accounting, Management and Policy Journal*, *11*(7), 1129–1158. https://doi.org/10.1108/SAMPJ-04-2019-0150

Scarpellini, S., Valero-Gil, J., Moneva, J. M., & Andreaus, M. (2020). Environmental management capabilities for a "circular eco-innovation." *Business Strategy and the Environment*, *29*(5), 1850–1864. https://doi.org/10.1002/BSE.2472

Sharma, M., Joshi, S., & Kumar, A. (2020). Assessing enablers of e-waste management in circular economy using DEMATEL method: An Indian perspective. *Environmental Science and Pollution Research*, *27*(12), 13325–13338. https://doi.org/10.1007/S11356-020-07765-W/FIGURES/4

Stumpf, L., Schöggl, J. P., & Baumgartner, R. J. (2021). Climbing up the circularity ladder? – A mixed-methods analysis of circular economy in business practice. *Journal of Cleaner Production*, *316*, 128158. https://doi.org/10.1016/J.JCLEPRO.2021.128158

Sunderland, T. (1997). *Environmental Management Standards and Certification. Do they add value? Inside ISO 14001 and beyond*. Greenleaf Publishing.

US EPA. (2022, September). *Learn About Environmental Management Systems*. https://www.epa.gov/ems/learn-about-environmental-management-systems#what-is-an-EMS

van Eijk, F. (2015). *Barriers & Drivers towards a Circular Economy Literature Review*. https://circulareconomy.europa.eu/platform/en/knowledge/barriers-drivers-towards-circular-economy

Vermeulen, W. J. v, Reike, D., & Witjes, S. (2019). *Circular Economy 3.0 - Solving confusion around new conceptions of circularity by synthesising and re-organising the 3R's concept into a 10R hierarchy*. www.uu.nl/

Voss, C. A. (2005). Paradigms of manufacturing strategy re-visited. *International Journal of Operations and Production Management*, *25*(12), 1223–1227. https://doi.org/10.1108/01443570510633620/FULL/PDF

Watson, S. A. (1996). The business implications of implementing ISO 14000. *Environmental Quality Management*, *6*(1), 51–62. https://doi.org/10.1002/TQEM.3310060109

Willson, R. (2019). Transitions theory and liminality in information behaviour research: Applying new theories to examine the transition to early career academic. *Journal of Documentation*, *75*(4), 838–856. https://doi.org/10.1108/JD-12-2018-0207

Yang, Y., Chen, L., Jia, F., & Xu, Z. (2019). Complementarity of circular economy practices: an empirical analysis of Chinese manufacturers. *International Journal of Production Research*, *57*(20), 6369–6384. https://doi.org/10.1080/00207543.2019.1566664

Yuan, X., Liu, M., Yuan, Q., Fan, X., Teng, Y., Fu, J., Ma, Q., Wang, Q., & Zuo, J. (2020). Transitioning China to a circular economy through remanufacturing: A comprehensive review of the management institutions and policy system. *Resources, Conservation and Recycling*, *161*, 104920. https://doi.org/10.1016/J.RESCONREC.2020.104920

Zorpas, A. A. (2020). Strategy development in the framework of waste management. *Science of The Total Environment*, *716*, 137088. https://doi.org/10.1016/J.SCITOTENV.2020.137088