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Innovation in a Circular Economy: Conceptual, empirical and policy underpinnings for transition through an eco-innovation pathway

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The stakes are immense, the task colossal, the time is short. But we may hope–we must hope–that man's own creation, man's own genius, will not destroy him. Scholars, indeed all men, must move forward in the faith of that philosopher who held that there is no problem the human reason can propound which the human reason cannot reason out.

Albert Einstein - "Only Then Shall We Find Courage" in *N.Y. Times Magazine*, (23 June 1946).

Declarações

Declaro que esta tese é o resultado da minha investigação pessoal e independente. O seu conteúdo é original e todas as fontes consultadas estão devidamente mencionadas no texto, nas notas e na bibliografia.

O candidato,

Lisboa, 4 de Abril de 2018

Declaro que esta tese se encontra em condições de ser apreciado pelo júri a designar.

O(A) orientador(a),

Lisboa, 4 de ABRIL de 2018

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INNOVATION IN A CIRCULAR ECONOMY:

CONCEPTUAL, EMPIRICAL AND POLICY UNDERPINNINGS FOR TRANSITION THROUGH AN ECO-INNOVATION PATHWAY

ANA ISABEL DE JESUS CORREIA FERNANDES OLIVEIRA SILVA

ABSTRACT

As the world seeks answers to the defining challenges of climate change and environmental sustainability, several hypotheses are being canvased in the search for a solution to decouple economic growth and social development from resource exploitation. Among those, the circular economy (CE) emerged as an operational response defined by its opposition to a harvesting-wasting economic model, proposing instead restorative and regenerative activities. But reconfiguring existing paradigms is not trivial.

Aligning innovation activities with more sustainable paths is a central requirement for the desired socio-techno-economic paradigm shift. This work proposes that a new pathway is needed for gearing the sustainable innovation agenda towards a CE, and foster structural change. CE-inducing eco-innovation (EI) must, however, be monitored and measured, and implications to socio-cultural agents, organisational strategies and policy priorities have to be bore in mind, if we are to ascertain if progress is being made.

As CE and the EI – CE nexus research is still in its early days, this work adds to the discussion by contributing (1) to the theoretical development of these concepts and their interrelations; (2) to the empirical definition of pro CE EI proxies; and (3) to the prospective anticipation of CE developments. Within the sustainability debate, and using an innovation studies perspective, this research adopted a mixed methods approach, using both quantitative and qualitative methods such as literature reviews, bibliometrics, patent and trademark analysis (using the specific case of Portugal), and foresight techniques (Delphi study).

The overall findings suggest that CE's main ideas are arguably timely. CE's establishment within the sustainability debate seems, nevertheless, dependent on overcoming short term barriers constraining its further development, of technological and economic nature, but also of a socio-cultural kind. CE is argued as a multidimensional, multi-actor approach reliant on "systemic transformative" innovation, thus dependent on a combination of "harder", (technological, R&D-driven), and "softer" (non-technological change in social and business culture) knowledge. The empirical diagnosis of an innovation system's pro circularity tendencies proved to be informative as to assess convergence to circularity. In the Portuguese case, it successfully shed light on ongoing dynamics related with signs of effective transformation towards CE activities, even if highlighting structural limitations associated with systemic failures regarding actors and networks.

Redirecting *innovation systems* towards a more "circular" paradigm is, therefore, deeply dependent on an institutional "coordination role" enabling "framework conditions" directly linked to a *systemic action*. That is, associating bottom-up measures to top-down policies in a coherent strategic roadmap, in order to avoid mismatches and contradictory incentives. This pointed to the usefulness of rethinking innovation policy design. In one hand, to address market and system failures, leading to underinvestment and lack of connectivity in innovation. In the other hand, to promote the diffusion of CE related information for enterprises and civil society, in order to encourage market awareness and change mind-sets towards "circular" behaviours. As the conceptual and practical implementation challenge remains pressing, this work added important underpinnings for fine-tuning a CE inducing "policy mix".

KEYWORDS: Globalisation; circular economy; eco-innovation; patents; trademarks; Delphi study

RESUMO

Num mundo crescentemente interdependente, as alterações climáticas e a sustentabilidade ambiental são questões globais complexas. A importância de dissociar desenvolvimento da exploração de recursos tem propiciado um alargamento de horizontes a novos conceitos. Nesse contexto, a economia circular emergiu como uma resposta operacional, definida pela sua oposição ao modelo económico atual de exploração/desperdício. Contrapõe, ao invés, processos restaurativos e regenerativos. A reconfiguração dos paradigmas existentes, a este nível, não é, contudo, algo trivial.

Uma vez que o alinhamento das atividades de inovação com objetivos mais sustentáveis é um requisito central na alteração de paradigma sócio-tecno-económico, este trabalho foca a necessidade de orientar a agenda de inovação para a "circularidade". A eco-inovação pro-circularidade deve, no entanto, ser monitorizada e medida, e as implicações para os agentes socioculturais, estratégias organizacionais e prioridades políticas levadas em conta, se quisermos verificar o seu progresso.

Nesse âmbito, pretendeu-se contribuir para o debate em curso contribuindo para: 1) uma melhor compreensão teórica do papel da eco-inovação na implementação de uma economia circular; 2) a definição e teste de *proxies* empíricas de inovação pro-circularidade; 3) o desenvolvimento de uma visão prospetiva de futuros desenvolvimentos nesta área. No contexto do debate da sustentabilidade, e usando uma perspetiva baseada nos estudos da inovação, foram adotados métodos quantitativos e qualitativos, incluindo revisões de literatura, métodos bibliométricos, análise de patentes e de marcas comerciais (usando o caso específico de Portugal), assim como o uso do método prospetivo Delphi.

As conclusões gerais sugerem que as principais ideias da economia circular são indiscutivelmente oportunas. Dentro do debate da sustentabilidade o estabelecimento de uma economia circular parece, no entanto, dependente de se vencerem barreiras de curto prazo, de natureza tecnológica, económica e sociocultural. A abordagem preconizada pela economia circular é assim tida como multidimensional, multi-ator, dependente de uma inovação sistémica "transformadora", compreendendo não só inovação tecnológica, mas também mudanças institucionais abrangentes quanto a políticas públicas, mercados e práticas sociais. O diagnóstico empírico das tendências pró-circularidade de um sistema de inovação provou ser informativo nessa avaliação. No caso português, permitiu conhecer as atuais dinâmicas, sublinhando sinais de transformação efetivas em direção a atividades circulares, ao mesmo tempo que assinalou as limitações estruturais associadas a falhas sistémicas quanto aos atores e redes (interconexões). Redirecionar os sistemas de inovação para um paradigma mais "circular" é, portanto, profundamente dependente de um "papel de coordenação" institucional que permita "condições de enquadramento" diretamente ligadas a uma ação sistémica. Isto é, associando medidas *bottom-up* e *top-down* num roteiro estratégico coerente, a fim de evitar desequilíbrios e incentivos contraditórios. Importa, por isso, repensar igualmente os instrumentos das políticas de inovação. Por um lado, resolvendo falhas de mercado e sistema, que levam a sub-investimento e falta de conectividade. Por outro, promovendo a difusão de informação para empresas e sociedade civil, a fim de estimular a conscientização e mudar mentalidades em relação a comportamentos "circulares".

O desafio de implementação continua a ser premente, este trabalho pretendeu contudo acrescentar ao debate tendo em vista contribuir para o ajuste do "mix de políticas" indutoras de circularidade.

PALAVRAS-CHAVE: Globalização; economia circular; eco-inovação; patentes, marcas registadas; Delphi

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NOTATIONS AND ABBREVIATIONS

CE	Circular economy
CCMT	Climate change mitigation technologies
CIS	Community Innovation Survey
COMPETE	Programa Operacional Competitividade e Internacionalização (Operational Program Competitiveness and Internationalisation)
COP	Conference of Parties
CO_2	Carbon dioxide
CPC	Cooperative Patent Classification
CTM	Community Trademarks
C2C	Cradle to Cradle
EC	European Commission
ECB	The European Central Bank
ECLA	European Classification System (Patents)
Eco-IS	Eco-Innovation Scoreboard
EI	Eco-innovation
EIO	Eco-Innovation Observatory
EMAS	Eco-Management and Audit Scheme
EMF	Ellen MacArthur Foundation
EPC	European Patent Convention
EPO	European Patent Office
EU	European Union
EUIPO	European Union Intellectual Property Office
EU TM	EU trademark
FDI	Foreign Direct Investment

GDP	Gross domestic product
GGC	Green Growth Commitment
ICT	Information and communications technologies
ICTSD	International Centre for Trade and Sustainable Development
IMF	International Monetary Fund
IPC	International Patent Classification
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual property right
ISO	International Organization for Standardization
ISQ	Sustainable Innovation Centre (Portugal)
LCA	Life-cycle analysis
LNEG	Laboratório Nacional de Energia e Geologia (Portugal)
MCI	Material Circularity Indicator
MFA	Material flow analysis
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OHIM	Office for Harmonisation in the Internal Market
PAEC	Portuguese Action Plan for the Circular Economy
PATSTAT	Worldwide Patent Statistics Database
POSEUR	Operational Plan for Sustainability and Resource Efficiency
PROINOV	Programa Integrado de Apoio à Inovação (Integrated Program for Innovation Support)
R&D	Research and development
RMC	Raw Material Consumption indicator -
SME	Small and medium enterprises
S&T	Science and Technology

UN	United Nations
UNCED	UN Conference on Environment and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UK	United Kingdom
US	United States of America
WEF	World Economic Forum
WIPO	World Intellectual Property Organization
WoS	Web of Science
WWF	World Wildlife Fund

CHAPTER 1

INTRODUCTION

Growing scientific evidence of the inherent limits of natural resources and anthropogenic degradation of the environment, due to the resource/energy-intensive trajectories, emphasise the inadequacy of current global demand and consumption trends. As resource consumption, dependence, depletion, volatility and costs continue to be on the rise, the need to decouple revenues from material input and improve resource performance across the economy has already led to a search of different socio-economic hypothesis. Within the sustainability debate, and focusing on the circular economy (CE) and eco-innovation (EI) themes, this research expand the knowledge on the EI role in the implementation of the CE approach by contributing (1) to the theoretical development of these concepts and their interrelations; (2) to the empirical definition of pro CE EI proxies; and (3) to the prospective anticipation of CE developments. This first chapter defines the background and motivation of the research. It focuses on the study's relevance, research questions, scope definition and research structure.

1.1. Background and motivation

Continued human use and abuse of natural resources is pushing global ecosystems to the brink. Several global tipping points have already been reached, increasing the risk of cascading irreversible environmental changes (Rockström et al., 2009). Recent decades have highlighted the importance of decoupling economic growth and social development from resource exploitation and waste. One of nowadays defining challenges seems to be how to accommodate economic development among competing countries, and the continuous rise of living standards of a world population estimated to reach 10 billion by 2050, in a context of limited natural resources, without jeopardising the sustainability of the global environment (OECD, 2012).

In the light of the limitations of the conventional economy, a more circular approach is gaining traction. A view referred to as the "circular economy" (CE) has been put forward as a strategic approach, placing closed-loop thinking at the heart of businesses, industrial organisation and national agendas (Preston, 2012). Inspired on natural ecosystems, the CE postulates moving away from a notion of a linear system (based on unidirectional extraction, production, distribution, consumption and disposal activities) towards a permanently regenerative economy. It focuses on the design of processes and products aiming to minimise negative environment and societal impacts, reducing the use of non-renewable resources, eliminating toxic and hazardous materials, and increasing product lifespan, as well as maximising the potential for reusing products and recovering materials (IAU, 2013). It proposes instead models for value creation that support sustainable economic development, through loops of reuse, restoration and renewability, where waste is residual or converted into an input for other processes, thus shifting the emphasis to the provision of functionality and "service" rather than ownership and material production (EMF, 2012; Stahel and Reday-Mulvey, 1981).

Building on early definitions from the second half of the 20th century, CE ideas have gained additional relevance as a research topic over the last decade (Andersen, 2007), driven by the efforts of international organisations such as the United Nations (UNEP, 2014) and the European Union (EC, 2015a), as well as the work of private agents such as the Ellen MacArthur Foundation (EMF, 2012, 2013, 2014a). Nevertheless, "while businesses and governments are recognising the need for change, there is confusion on what needs to be changed and how it can best be accomplished." (Schulte, 2013, p. 47)

Meanwhile, eco-innovation (EI) has been emphasised as a core driver for change in the transition to sustainability (Kemp, 2010). It is defined as innovation, in all of its forms (product, process, marketing, organisational - see OECD, 2005), yielding both ecological and economic gains (Carrillo-Hermosilla et al., 2010). In other words, the concept has been recognised as a key element in the development of competitive technologies and institutional forms (including new business models) that allow "environmental benefits", including greater efficiency in consumption and use of resources (EC, 2012). In the policy arena, EI has been called "a catalyst" of a CE (Potočnik, 2014) and a key component in the transition from a linear to a circular system of production and consumption (EIO, 2016).

However, an analysis of the intersection of the CE and EI concepts seems lacking, with few studies considering the explicit importance of EI in the transition to a CE (EIO, 2016). If aligning innovation activities with a more sustainable path is a central requirement for a socio-techno-economic paradigm shift (Mirata and Emtairah, 2005), how can the innovation agenda be geared towards a CE? What changes are instrumental for such a structural break? How can CE-inducing EI, be monitored and measured? What are the implications to socio-cultural agents, organisational strategies and policy priorities?

More comprehensive research seems instrumental to grasp such a transformative transition. Understanding the role of EI towards a CE is, therefore, not only an academic endeavour, but may also help actors and institutions to better adjust and calibrate their CE efforts. Business actors, in particular, would benefit from this analysis, so as to be able to both redesign and pursue sustainable business models from the outset. As for policy makers, an integrated understanding of EI, and its relationship to CE, could underpin initiatives that take uncertainty and feedback loops into account.

1.2. Scope and research questions

Acknowledging the importance of more research in this area, this work contributes to the discussion by placing the role of innovation centre stage. Within the sustainability debate, and using an innovation studies perspective, this research draws on contributions from the fields of Sustainability, EI and CE[1] to systematise research at the point where these agendas intersect. The main question in discussion is how and in which ways can innovation contribute to the development of a CE. Particularly, what may be the role of EI in fostering a socio-techno-economic change towards a CE? As this is a broad question three operational sub-questions were defined:

- **RQ 1 -** How are CE and EI characterised and how the concepts are related (what are the relations between the different dimensions of EI and the various levels of a CE?)
- **RQ 2 -** How can indicators of socio-techno-economic change, i.e. CE-inducing EI, be operationalised? How can *innovation systems* circularity be assessed?
- **RQ 3 -** Which are the main socio-cultural, organisational, and policy implications of the CE-EI relation for redirecting innovation systems?

[1] This process takes advantage from the required three literature fields' analysis required by the doctoral programme. In the present case, sustainability, circular economy and eco-innovation were the fields identified. The reading lists for each of those literature fields' guided and enabled gathering relevant background information, as well as the identification of key research trends.

Considering these three sub-questions the main goals were to:

- Contribute to the growing debate about the fickle equilibrium between economic development, competitiveness, and the imperative necessity to tackle environmental degradation;
- Debate the potential role of a regenerative and EI driven CE in the transition towards a next socio-techno-economic paradigm;
- Explore and test an empirical approach to serve as a diagnosis tool of the “circularity” of a system;
- Question CE implementation, applicability and future developments;
- Discuss implications on how to redirect “innovation system” to “circular” practices.

To address these objectives the research was divided in three main parts (Table 1): an initial stage dedicated to the conceptual and theoretical background, focusing on mapping the literature; a second part concentrated on an empirical analysis regarding how to measure and monitor pro-CE EI; and a third part debating implications of previous findings and exploring main contributions of the EI- CE relation.

The first part, focusing on a literature review, seeks to identify relevant background information, as well as key research trends. It intends to provide an overview of the development of the CE and EI concepts, discussing working definitions and establishing bridges between both concepts. It also aims to enable the definition of EI dimensions most instrumental in achieving a CE at a variety of levels. In order to appreciate both the dynamics and the inertia of the CE, this part also tests an analytical framework for examining the role of technological (hard) and non-technological (soft) factors in its implementation. This kind of insight may be helpful in calibrating stakeholders’ circularity practices: to business players to gain understanding and enable first mover advantages in the pursuit of sustainable business models; to academia in further clarifying CE’s potential in the sustainability debate; to policy makers in gaining a comprehensive understanding of EI and its relations to CE as to better align government interventions, especially in innovation policy.

Research Question	Main objectives	Research method	Part
RQ 1 - How are CE and EI characterised and how the concepts are related (i.e. what are the relations between the different dimensions of EI and the various levels of a CE*?*)	-derive literature-based working definitions of EI and CE -review and assess the relationship between the different dimensions of EI and the various levels of a CE -generate an overview of the types of EI that may be instrumental in achieving a CE.	Literature review; conceptual analysis; bibliometric analysis	Part I - Circular Economy and Eco-Innovation: Theoretical background and conceptual approach
RQ 2 - How can indicators of socio-techno-economic change, i.e. CE-inducing EI, be operationalised? That is, how can innovation systems circularity be assessed?	-assess how pro-CE EI can be monitored. -reconfiguring innovation proxy “patents” to CE assessment -reconfiguring innovation proxy “trademarks” to CE assessment	Patent analysis; Trademark analysis	Part II - Innovation to a dynamic circular economy - assessing change [empirical application]
RQ 3 – Which are the main socio-cultural, organisational, and policy implications of the CE-EI relation for redirecting innovation systems?	-discuss CE within the sustainability debate -recognise future foreseeable developments of CE and EI role - provide insights on CE by addressing socio-cultural, organisational and policy priorities in encouraging CE.	Delphi method – Survey of CE specialists	Part III – Lessons from the Eco-Innovation/ Circular Economy nexus

Table 1 - Research questions, main objectives, methods and organisation

As a CE is argued as requiring multilevel, multi-actor, technological innovation, but also comprehensive institutional change in policies, markets and social practices, using the structures of the innovation system already in place may facilitate the transition. That is, redirecting innovation systems towards a more “circular” paradigm should improve CE dissemination and broader implementation. Therefore, the second part of this work explores ways to monitor pro-CE EI. Patents as a workable proxy for innovation and technological achievements towards a CE (what was called “hard” innovation) and trademarks as a complementary indicator based on symbolic and other intangible assets (what was called “softer” innovation) can be deployed to assess that dynamics. This kind of analysis may allow an overview of CE implementation that can be of use to priority identification and policy definition, i.e. a CE Roadmap. This adds to the efforts for developing new and insightful datasets and toolboxes employed to map and measure the emergence of transformative change in the contemporary economy.

As for the third part, the use of foresight techniques, namely the Delphi method both complements and tests the sensitivity of previous literature reviews and the data acquired in the empirical exam. In an emerging theme, as is the case with the CE, the use of the Delphi method empowered an enriched debate regarding the discussion of previous insights, recognising future foreseeable developments concerning socio-cultural factors, organisational strategies and policy priorities.

1.3. Research design and outline

Taking into account the inherent specificity of each one of the three research questions main goals, and drawing on Creswell’s Model for Research Design, a Pragmatism worldview was employed (Creswell, 2013). “Pragmatism” is a movement originated around the 1870’s, in the American philosophical tradition, deriving from the work of Charles Sanders Peirce (1839–1914), William James (1842–1910) and John Dewey (1859–1952) (Hookway, 2013). It revolves around the notion that the function of thought is instrumental, a tool for action and problem solving. It is not so much a philosophical position among others, as it is a set of philosophical tools that can be used to address problems (Tashakkori and Teddlie, 2003, p. 7). Pragmatism is not, therefore, committed to any one system of philosophy as it does not see the world as an absolute unity. It looks to the knowledge claims arising from actions, situations and consequences, rather than antecedent conditions (as in post positivism) recognising that research always occurs within social, historical and political contexts (Creswell, 2013). As it is solution focused, aiming to look into the "what" and the "how", it seemed the best choice *vis-à-vis* the research objectives.

As this worldview assumes that there is not a “correct", or a unique, methodology to address complex and heterogeneous phenomena, it advocates the use of the methods and data collection that best suit the needs and objectives of the research (Cherryholmes, 1992; Creswell, 2013; Leech and Onwuegbuzie, 2009). A mixed method approach can be challenging, as it is time intensive, demands extensive data collection and knowledge on both quantitative and qualitative forms of research (Tashakkori and Teddlie, 2003, p. 19). Notwithstanding, the combination of empirical inputs (quantitative and qualitative), with mutually reinforcing findings, allows a more comprehensive and integrative study.

As the three research questions are fairly different (both in nature and in degree of pre-existent studies and findings) each required different methodological approaches. Consequently, the research follows the layout represented in Figure 1 and was structured in three parts with a total of 9 chapters (Table 2).

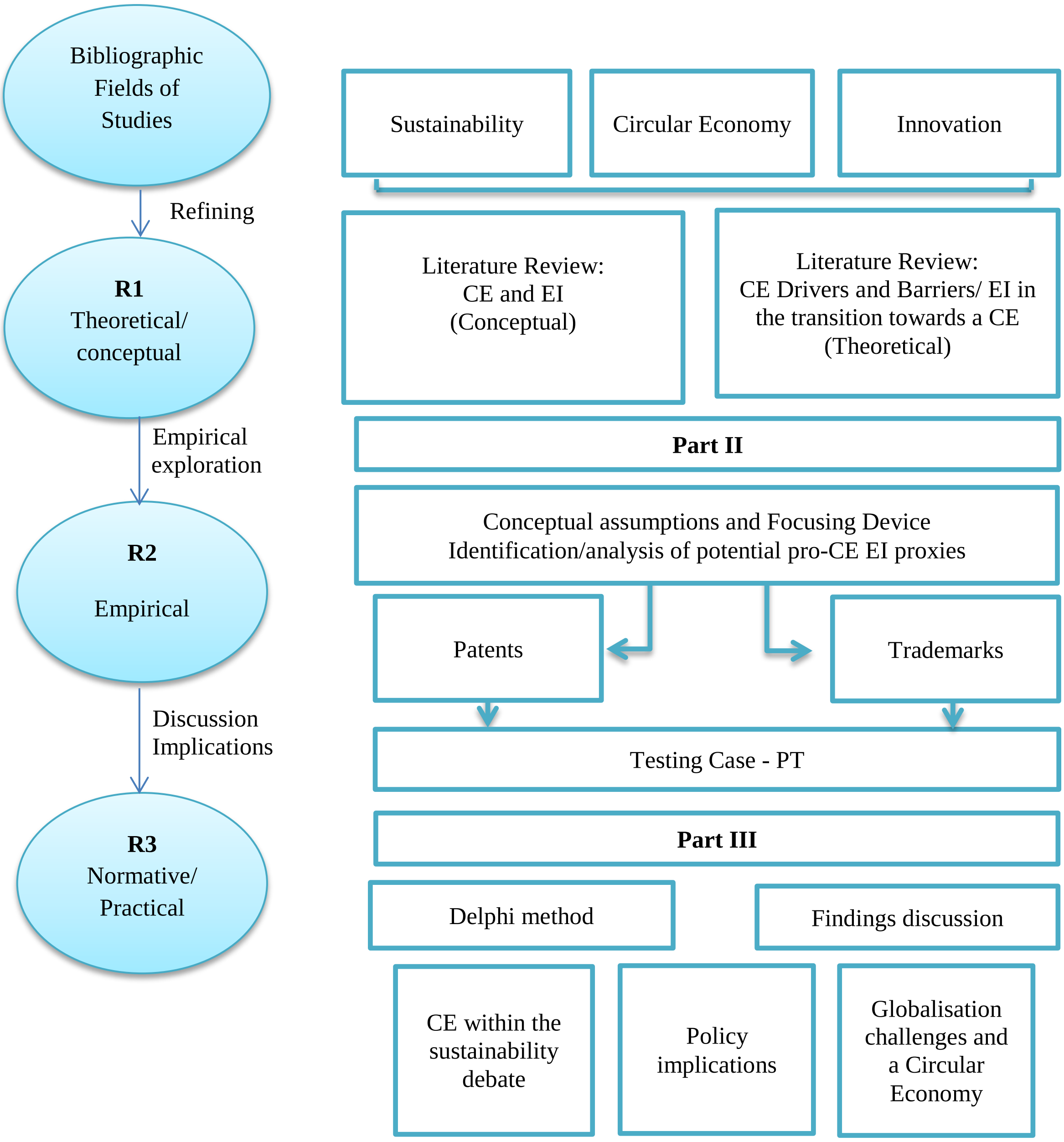

Figure 1 - Research layout scheme

Part I aims to explore current knowledge on the concepts of CE and EI, establishing literature-based working definitions of both concepts. Several methodologies were applied in the literature review to enable a broad view and give content to the conceptual nuances of EI and CE. A bibliometric analysis and an academic and grey literature systematic survey were the approaches used. Chapter 2 examines the construction of both CE and EI concepts exploring main theoretical developments. Chapter 3 reviews the role of EI at CE's macro, meso, and micro levels; and characterises CE-inducing EI in terms of targets, mechanisms and impacts. Chapter 4 using EI heuristics, map CE trajectories charting out the drivers that promote or streamline a CE, as well as the barriers that most frequently derail it, or slow it down.

Part II focuses on the empirical diagnoses of innovation systems circularity capacities. An empirical approach for studying (eco-)innovation systems in the development of a CE was developed and indicators identified and used in a practical case. Patents and trademarks were acknowledged as a means to acquire some new and fresh insights on both technological and non-technological "circularity" of EI systems, using Portugal as subject case. Chapter 5 discusses how CE and EI have been individually assessed, identifying indicators advantages and limitations; and proposing an empirical approach to gather new insights in the anticipation, understanding and evaluation of progress towards a circular system. Chapter 6 debates the advantages and limitations of using patents as a meaningful indicator of pro-circular "hard" innovation and presents a possible empirical application. Chapter 7 reviews the rationale for a softer approach to socio-techno-economic paradigm change and summarises the case for trademarks as a meaningful indicator of non-technological "soft" pro-circular innovation.

Part III is more normative in nature gathering the insights of institutional sectors (public, business, academic actors as well as NGOs) concerning the CE approach and its key priorities and future developments (Chapter 8) and discussing overall implications and concluding remarks (Chapter 9). Chapter 8 uses a Delphi study to gather the insights of several stakeholders (namely academic and industry experts) in the assumption that key features of the CE are best understood by the actors involved in its development and dissemination. The chapter discusses CE within the ongoing global debate on sustainability, extracting the insights and main implications of the CE-EI relation to socio-cultural agents, organisational strategies and policy priorities. Chapter

9 concludes, reflecting on main findings and implications. It examines this work's contributions, its integrated response to the research questions, while addressing main limitations and future avenues for research.

	Part I - THEORETICAL BACKGROUND AND CONCEPTUAL APPROACH	Part II – INNOVATION TO A DYNAMIC CIRCULAR ECONOMY - ASSESSING CHANGE [EMPIRICAL APPLICATION]	PART III –LESSONS FROM THE ECO-INNOVATION/ CIRCULAR ECONOMY NEXUS
Chapter 1	Introduction Defining background, motivation, research questions, and research structure		
Chapter 2	Conceptual Definition EI-CE		
Chapter 3	EI-CE connections by level		
Chapter 4	Enabling and constraining factors in the EI-led transition to a CE		
Chapter 5		Indicators of transformational socio-techno-economic change	
Chapter 6		Patents as indicator	
Chapter 7		Trademarks as an indicator	
Chapter 8			Main socio-cultural, organisational, and policy implications of the CE-EI relation
Chapter 9	Concluding remarks Discussing overall findings and implications		

Table 2 - Structure of the research: Main functions of each chapter

PART I – CIRCULAR ECONOMY AND ECO-INNOVATION: THEORETICAL BACKGROUND AND CONCEPTUAL APPROACH

The circular economy (CE) notion has emerged as a key approach in the transition to a more sustainable economic paradigm. It highlights what is to be rejected, the linear “take-make-dispose” economy, and instead proposes a “system that is restorative or regenerative by intention and design.” (EMF, 2012, p. 7) Furthermore, a CE is not described necessarily as a disruptive concept, but rather as a workable socio-technical approach for attaining economic and ecological sustainability. It is depicted as a framework compatible with companies’ and countries’ needs to reduce input costs, as well as desires to operate in a world with less unpredictability (WEF, 2014).

Identifying the determinants of this societal transition is challenging (Stirling, 2011). One reason is that a CE is still difficult to describe, comprising diverse areas, including: sustainable production-consumption systems; closed-loop supply-chains; and product-service systems. Thus, despite its status as a transition hypothesis towards a new socio-technical regime, the CE is still a rather poorly understood notion. Additionally, the methodologies for actually delivering a CE are even more blurred and uncertain. Hence, it is important to develop a thorough understanding of the factors that foster and hinder the transition to a CE. As eco-innovation (EI) appears as a core driver for change in the transition to sustainability (Kemp, 2010) and a key component in the transition from a linear to a circular system, an analysis of the intersection between CE and EI could provide important findings, especially since few studies have been considering the explicit importance of EI in the transition to a CE (EIO, 2016). Through a perspective informed by the innovation systems view and the more recent “transformation turn” in innovation studies, the first part of this research aims to collect, analyse and interpret relevant literature in the intersection of these two fields. Chapter 2 lays on the discussion of CE and EI concepts and their theoretical developments. Chapter 3 draws on academic contributions from the fields of EI and CE to clarify and synthesise findings, especially reviewing the role of EI at CE’s macro, meso, and micro levels, and characterise CE-inducing EI in terms of targets, mechanisms and impacts. Chapter 4 adds non-academic literature to the previously analysed academic corpus, focusing on drivers and barriers and offering a framework for analysis of the challenges for a green structural change of the economy.

CHAPTER 2

THE CIRCULAR ECONOMY AND ECO-INNOVATION CONCEPTS UNDER SCRUTINY

Even if one can intuitively argue that eco-innovation (EI) and the circular economy (CE) are closely related, and assume that achieving a CE without EI is unlikely, it remains to be seen in what specific ways this is so. Certainly not all EI is linked to a CE, and not all dimensions of CE require innovation. However, a zone of overlap is bound to exist. Therefore, in order to ascertain which innovations are more compatible with CE models, and how a CE is to be achieved through socio-techno-economic change, a clearer understanding of the two concepts is useful. In the next sections definitional issues regarding the CE (section 2.1 and 2.2), and EI (sections 2.3 and 2.4) will be discussed.

2.1. Transition to sustainability through Circular Economy-inducing approaches: the family of Circular Economy friendly concepts

For its most part the global economy remains a system where activities, from tangible production to intangible contracts, routines and regulations, take place within a linear model of open-ended "take-make-dispose" resource exploitation. Notwithstanding the growing awareness that the use of the Earth's resources cannot be limitless, and the dissemination of related concepts, such as corporate social responsibility, this linear model remains essentially unchallenged (although future-oriented debates go back a long time, see Mendonça, 2017). Moreover, moving away from this model will not be an easy task, as entrenched technical systems are made stiffer by risk avoidance and special interests with much to lose in the short run (Markard et al., 2012; Schulte, 2013).

In the post-Paris COP 2015 context, expectations are high, with 175 governments (174 countries and the European Union) signing the initial agreement, originally with the United States and China among them (COP21, 2016). However, various actors' interests do not align well, as the promotion of national economic competitiveness, in a fiercely dynamic global market, comes to terms with the impacts of continued environmental degradation. A new set-up may need to be based on "decoupling" development from resource consumption, by focusing on extended material life-cycles, reuse, re-manufacturing and recycling (UNEP, 2011). If the need for change is increasingly recognised, the specific pathways of transition remain much less defined. A number of perspectives for framing the discussion have been proposed in the literature, which have been instrumental in shaping the current understanding of the CE. Table 3 presents salient examples of these.

CE related concepts	Links with CE	Focus	Sources
Closed-loop economy	"man must find his place in a **cyclical ecological system**". "highlighted the potential of a **closed-loop economy** impact on competitiveness, job creation, resource savings and waste prevention".	Focus on the need to "close" the loop in economical systems	Boulding, 1966, p. 9 Stahel and Reday-Mulvey, 1981, p. 93
Industrial ecology	"By analogy with natural ecosystems, an industrial ecology system (…) **maximizes the economical use of waste materials and of products** at the end of their lives as inputs to other processes and industries". "Industrial ecology involves **designing industrial infrastructures as if they were a series of interlocking ecosystems**". "Moving **from linear throughput to closed-loop material and energy use** are key themes in industrial ecology".	Focus on emulating natural processes "closing the loop" in industrial systems	Frosch, 1992, p. 800 Tibbs, 1993, p. 3 Ehrenfeld and Gertler, 1997, p. 68
Industrial Symbiosis	"industrial symbiosis (IS) can be categorized as a concept of collective **resource optimization** based on **by-product exchanges** and **utility sharing** among different colocated facilities". Industrial symbiosis "traditionally separate industries in a **collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products**".	Focus on industrial clusters and synergies	Jacobsen, 2006, p. 240 Chertow, 2007, p. 314
Natural Capitalism	"Natural capitalism recognizes the **critical interdependence between the production and use of human made capital and the maintenance and supply of natural capital**".	Focus on environmental and economic benefits of more effective manufacturing processes, reuse and recycling of materials	Lovins et al. 1999, p. 3
Cradle To Cradle	"If humans are truly going to prosper, we will have to learn to imitate nature's highly effective cradle-to-cradle system (…) in which the very concept of **waste does not exist**".	Focus on design, since the conception of competitive goods/ services without environment impact	Braungart and McDonough, 2002, p. 103
Zero Waste	"Zero Waste means designing and managing products and processes to systematically avoid and **eliminate the volume and toxicity of waste and materials, conserve and recover all resources**, and not burn or bury them". "Zero waste is a unifying concept for a range of measures aimed at eliminating waste and challenging old ways of thinking. Aiming for zero waste will mean **viewing waste as a potential resource** with value to be realised, **rather than as a problem to be dealt with**". "At this moment, ZW strategy is targeted toward zero landfills through **diverting waste from landfills**".	Focus on limiting waste and diverting it from landfills	ZWIA, 2009 unpaginated Curran and Williams, 2012, p. 3 Zaman, 2015, p. 17
Functional Service Economy	"A functional economy (…) is one that **optimizes the use (or function) of goods and services** and thus the management of existing wealth (goods, knowledge, and nature). The economic objective of the functional economy is to create the highest possible use value for the longest possible time while consuming as few material resources and energy as possible". "The Functional Service Economy is a set of innovative business models **that integrate products and services (…) to create health and jobs with considerably less resource consumption**".	Focus on new business models	Stahel, 1997, p. 91 Stahel, 2010, p. 2

Table 3 - Examples of CE-related concepts
Note: Main linkages with the CE concept highlighted in bold.

Several ideas behind the CE concept are not new practices (Reike et al., 2018). Animal waste by-products (e.g. pelts, blood and bones) have been used at least since Neolithic times in the making of other items, such as fabrics, shelters, weapons and jewellery (Desrochers, 2000). Similarly, even in the 19th century, the potential benefits arising from cooperative arrangements between manufacturers and consumers, through by-product exchange and service bartering, were already being enacted (Simmonds 1862,1875 in Desrochers, 2000). The integrated concept of the CE emerged in the late 20th century, alongside concerns regarding planetary-level resource exhaustion; e.g. Boulding's (1966) "spaceman economy" advocacy, which stressed the need to find a new balance in a "cyclical ecological system"; and Georgescu-Roegen's (1971) entropy approach to the economic system. CE as a label first appeared in Pearce and Turner (1990), discussed in a full chapter, where the case for the economic practicality of environmental values was developed, referring to the works of Boulding and Georgescu-Roegen, and arguing that natural systems also have waste but, unlike the traditional open-ended economy, they absorb and recycle it. The authors argued for "circular" material flows in the man-made economy. An economic system organised like nature, operating in loops, would reduce the need for new inputs, and delay the depletion of the "environment" (as a source of materials and as a waste sink). Resources should not simply end up as litter after usage, or as products that are simply designed to accommodate the next wave of supply; they should rather be transformed from one form to another, and converted back to new resources.

The notion of the CE eventually infused the field of "industrial ecology", especially in the United States of America (US), popularised by Robert Frosch and Nicholas E. Gallopoulos (1989) and Robert Ayres (1998). Industrial ecology literature explicitly proposes the mimicking of natural systems' strategies as an industrial organisation template. It stresses the need for "material symbiosis" amongst different businesses and production processes, converting waste by-products into material inputs (Andersen, 2007, p. 133). In Europe, the industrial symbiosis concept has been taken up by many institutions and is widely used. The focus is on a "systems integration" view of companies exchanging by-products, closing each other's materials' cycles, and this is seen as an element that directly promotes CE implementation (Chertow, 2007; Lombardi and Laybourn, 2012).

In the late 1990's and early 2000's, critiques of traditional "industrial capitalism", which paradoxically both endangers the environment while also depending on it for natural resources, offered the notion of "natural capitalism" (Lovins et al., 1999). In this frame, environmental and economic benefits are based on more effective manufacturing processes, reuse and recycling of materials, in tune with CE considerations.

Other features of the CE can be found in the development of the "Cradle to Cradle" approach that focuses on the design of products and systems emulating/learning from nature's processes (e.g. biomimicry), seeking to create efficient, waste free, products/systems (Braungart and McDonough, 2002). It encourages eco-design and eco-efficiency opposed to a "planned obsolescence" industrial/marketing doctrine where human civilisation has already an ecological footprint of 1.5 Earths (Washington, 2015). That is, rather than solely improving resource use, it encouraged systems redesign toward a macro-complementary nexus of waste-free micro-solutions.

Additional contributions include several concepts following the 3R principles of "reduction, reuse and recycle", as well as the "zero emission", "zero waste" concepts referring to systems where natural cycles are emulated and waste averted (Pauli, 2010, 1997; Zaman, 2015; ZWIA, 2009). Recycling is central to a CE (Murray et al., 2017), but the latter is more than just *re-cycling*. As Washington (2015, p. 125) emphasises "recycling is really the aspirin to alleviate our collective hangover of overconsumption." CE stresses *downcycling* (i.e. de-using) and *upcycling* (i.e. creative re-usage) through radical approaches such as the "performance economy" where "ownership" is replaced by "services" (Stahel, 2010) or "extended producer responsibility", i.e. the fundamental incorporation of environmental costs into the market price of the goods from the outset (EC, 2014a; Kopnina and Blewitt, 2015; Monier et al., 2014). The priority is on the *de*-use and *re*-use of materials already mined or acquired, and in products planed not to be disposed, but rather maintained and upgraded (Washington, 2015). This is a view that expands the potential of services in "cleaning-up" the economy. Stahel (2010, 1997, 1982) develops the argument that "servicing" minimises the use of new inputs, and maximises the use of a product over its life-time, while benefiting both manufacturers (who retain control over assets, enhancing their maintenance and recovery) and consumers (who pay only for benefits). Overall this would have expected impacts on competitiveness, job creation, resource savings and waste prevention, emphasising the conversion of strict manufacturing into a nexus of self-feeding services (Stahel and Reday-Mulvey, 1981).

With roots in different ideas and schools of thought, the CE thus emerges today as a wide-ranging concept, and all these various contributions must be considered in their specific contexts, as the CE has "different meanings and different roles and responsibilities for different stakeholders" (EIO, 2016, p. 9).

2.2. The "Circular Economy"

As the CE concept entered the policy arena it received a new boost. Germany showed an early interest in CE initiatives; for instance, its "Closed Substance Cycle and Waste Management Act" of 1996, tried to ensure environmentally-friendly schemes of waste disposal. In Japan the Basic Law for Establishing the Recycling-based Society of 2000 created a legal framework to induce a more recycling-based society (Preston, 2012; Su et al., 2013, p. 216). It was also made more practically relevant when it started to be discussed in China in 1998, and afterwards when it formally entered the language of the central government in 2002, as the country became the first to enact explicit policy regarding the CE (Geng et al., 2009b; Mathews and Tan, 2011; Zhu et al., 2010). Between 2005 and 2007, the CE concept was fostered through "two batches of circular economy pilots", in order "to promote circular economy philosophy into action, including key industries, key areas, key enterprises and urban demonstrations" (Dong et al., 2013a, p. 228). In 2008, the Circular Economy Promotion Law was approved, coming into effect in 2009, to improve "resource utilisation efficiency, protecting the natural environment and realising sustainable development" (Geng et al., 2012, p. 216). This orientation was reinforced in the 12th Five-Year Plan (2011-15), focusing on cleaner production and eco-industrial park development (Geng et al., 2009b; Shi et al., 2010; Xue et al., 2010). The concept has also been taken as an actual policy enacting device benefiting from several funding opportunities within the EU Circular Economy Action Plan (EC, 2017a, 2015a).

This does not mean that the CE is a consensual concept, or even that its definition is settled (Kirchherr et al., 2017; Korhonen et al., 2018a). Many different recent definitions can be found, from international organisations, non-government organisations and academia (Table 4).

Some of the most recent examples of definitions and descriptions of the CE	References
Regarding Chinese implementation of CE, it is defined as "the realisation of a **closed loop of materials** flow in the whole economic system".	Geng and Doberstein, 2008, p. 232
In China "The term 'circular economy' (…) is a generic term for **reducing, reusing and recycling activities** conducted in the process of production, circulation and consumption".	Standing Committee of the National People's Congress (China), 2009, Art. 2
"It incorporates myriad strategies to achieve greater **efficiency** through economies of **systems integration**".	Geng et al., 2012, p. 216
One of the most used CE definitions is that of a "**system** that is **restorative or regenerative by intention and design**".	EMF, 2014a, p. 12
In Europe, CE has been defined as a way to keep "**the added value in products for as long as possible and eliminate waste**".	EC, 2014d, p. 2
The concept has integrated policy discourse as a way to "boost the EU's competitiveness by protecting businesses against scarcity of resources and volatile prices, helping to **create new business opportunities** and **innovative**, **more efficient ways of producing and consuming**".	EC, 2015a, p. 2
Regarding CE characteristics "essential elements of a circular economy (…) include: **refurbish, sharing/leasing, remanufacture, recovery, and repair** while **reduce** (in the sense of waste prevention and minimisation of hazardous substances) plays also a prominent role".	EIO, 2016, p. 10
"Central elements of the circular economy include **remanufacturing and product life-cycle extension** schemes such as re-use and refurbishment".	UNEP and UNECE, 2016, p. 246
"the concept of a circular economy (CE) is considered as a solution for harmonizing ambitions for **economic growth and environmental protection**".	Lieder and Rashid, 2016, p. 37
"By **promoting the adoption of closing-the-loop production** patterns within an economic system CE aims to **increase the efficiency of resource use**, with special focus on urban and industrial waste, to achieve a **better balance and harmony between economy, environment and society**".	Ghisellini et al., 2016, p. 11
"**Production** and **consumption** of goods through **closed loop** material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)."	Sauvé et al., 2016, p. 49
"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., 2017, p. 377
CE "as a regenerative system in **which resource input and waste, emission, and energy leakage are minimised** 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, p. 759
"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 r**ecovering** 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 p. 224-225
"Circular economy is an economy constructed from societal production-consumption systems that **maximizes** the service produced from the linear nature-society-nature **material and energy throughput flow**. This is done by using cyclical materials flows, renewable energy sources and cascading1-type energy flows. Successful circular economy contributes to all the three dimensions of sustainable development. Circular economy **limits the throughput flow** to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates".	Korhonen et al., 2018a, p. 39
"The circular economy is an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to **prevent the depletion of resources**, **close energy and materials loops**, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions and governments) levels."	Prieto-Sandoval et al., 2018, p. 610

Table 4 - Examples of definitions of the CE

Note: Main CE characteristics highlighted in bold

Nonetheless, the definitions do highlight a set of core elements which characterise the CE as encompassing: i) input minimisation and efficient use of regenerative resources (material and energy efficiency as well as sourcing and prioritising the use of renewable and non-hazardous materials); ii) life cycle extension and systems reconceptualization (repair, re-conditioning and re-manufacturing options; procurement, new business models based for instance on sharing or re-use; design - from policy design to life-cycle approach and eco-design); iii) output reduction, valorisation and waste minimisation, focused on recycling, networks of recovery, and valuing by-products and waste (Table 5). These components make up the CE, as a system deliberately designed to be restorative, replacing the end-of-life concept of the linear economy with new circular flows of reuse, restoration and renewability, in an integrated process, encompassing the entire value chain. In economic terms, the CE enables competitiveness through new ways of achieving more effective resource allocation, utilisation and productivity. Environmentally, the CE decreases negative externalities, and socially, it generates not only employment opportunities, but also, new "consumer" concepts (EMF, 2012, 2013).

	CE core elements	**Description**	**Literature examples**
I	Input minimisation and efficient use of regenerative resources	Strategy focused on the development of more efficient production models (implementation of options focused on reducing consumption of raw materials and energy).	Geng et al., 2010b; Ghisellini et al., 2016; Qinglan et al., 2013
II	Life cycle extension and systems reconceptualization	Extension of life. Strategy related with the expansion/ optimisation of product lifespan; the optimisation of the use of resources throughout the product life cycle; the reconceptualization of products to greater lifecycles from the outset (namely using eco-design); facilitate maintenance; increase traceability for reverse logistics; the development of repair, reconditioning and remanufacturing options; the improvement of materials recycling; automation and digital supports to new business models (from products to services, performance savings, sharing and leasing, etc.).	Bigano et al., 2016; Braungart et al., 2007; Castellani et al., 2015; Dalhammar, 2016; Hobson and Lynch, 2016; Kurilova-Palisaitiene et al., 2015; Tukker, 2004; UNEP and UNECE, 2016, p. 246; Vasantha et al., 2016)
III	Output reduction, valorisation and waste minimisation	Use of waste / by-products from one industry / sector as raw materials for another. Waste management and recycling of waste that cannot be reused or remanufactured.	Chertow, 2007; Iacondini et al., 2015; Sommerhuber et al., 2016; Walls and Paquin, 2015; WEF, 2014; Winkler and Kaluza, 2006.

Table 5 - CE Core elements

Due to its broad scope, arriving at a clear and compact definition of the CE remains somewhat elusive. A working definition of CE, in tune with the reviewed strands of analysis, could be given in terms of it being an approach towards sustainable development. This approach is achieved through several strategies aiming to reorganise production and social systems into regenerative environmentally-sound closed circuits. Its main characteristics are focused both on resource and waste minimisation, as well as processes of production and consumption designed from the outset for efficiency, reuse, repair, and recycling.

Three levels of analysis have been presented in the literature, on the basis of which the depth or granularity of CE implementation can be appreciated (Ghisellini et al., 2016). At a micro level, the CE focuses on individual actors, particularly companies (Yuan et al., 2006; Zhu et al., 2010). Examples include: eco-design and cleaner production strategies; resource efficiency initiatives; labelling systems, and; sustainable production and consumption methods (Geng et al., 2012, 2009b). At the meso level, the focus is on actor interaction especially inter-firm networks: industrial symbiosis; eco-industrial parks; green supply-chain management and reverse logistics (Zhu et al., 2010). As for the macro level, the CE is theorised at a national or global scale, with an emphasis on legislation; regulatory impact analysis; zero waste regimes; and recycling-oriented societies (Ghisellini et al., 2016; Zhijun and Nailing, 2007).

CE is therefore here considered as: *a multidimensional (micro, meso and macro), dynamic, integrative approach, promoting a reformed socio-technical template for carrying out economic development, in an environmentally sustainable way, by re-matching, re-balancing and re-wiring industrial processes and consumption habits into a new production-usage closed-loop system.*

2.3. Transition dynamics in an evolving economy: the "pro-environment" family of eco-innovation related concepts

Transition is an inherently innovation-intensive process of reconfiguration and adaptation. More than just "novelty introduction", innovation is embedded in a wider social and economic structure, rooted in a specific historical and territorial context (Freeman, 1987). Since the seminal writings of Joseph Schumpeter (Schumpeter, 1928), it has been acknowledged that innovation is not just newness *per se*. It is, rather, a "new combination" of ideas and factors of production. Innovation is not only about technical sophistication but also about adaptation to a usage context, i.e. it is the introduction of an ingenious proposition into a specific, and sometimes quirky, economic and institutional setting (Fagerberg et al., 2004). That is to say, innovation is not simply science and technology (S&T). From this perspective, innovation is not understood to be automatic, it is neither a linear output from increased research and development (R&D), nor a passive reaction to market signals (Caraça et al., 2009).

Moreover, innovation is not necessarily better: novel outcomes are not inevitably superior to the status quo, from a welfare or sustainability point of view (Soete, 2013). What is technologically feasible is not necessarily ethically desirable or environmentally sound (UNEP, 2011). The 20th century mass-production technological regime was extraction-based, creating on hindsight fundamental questions about the meaning of the very notion of "progress". One implication is that innovation concepts may be liable to some revision. As Schot and Kanger (2016, p. 25) stress, modifying "the way we innovate" is essential for transition. Transitions are complex dynamic processes involving a rich range of actors and discrete actions, and continued activities for a significant period of time, during which new products, services, business models and organisations emerge, either complementing or substituting incumbent ones, comprising an interacting sequence of technological and non-technological innovations (Markard et al., 2012; van den Bergh et al., 2011). As the environment became an area of prime policy concern, a cluster of concepts emerged concerning innovation focused on transition topics and broader societal challenges (Boons et al., 2013; Carrillo-Hermosilla et al., 2009; Rennings, 2000). This emerging "pro-environment" innovation agenda was beyond the scope of the industrial era (Freeman and Soete, 1997, pp. 414–23).

The entry and diffusion of an environmental angle of analysis into innovation studies has been characterised by some lexical variation. As innovation began to be conceived more and more as a dynamic process that evolves in real historical time and involves a multitude of different activities, not just formal R&D from a "high-tech" supply-side but also shaped by the social and cultural environment (Balconi et al., 2010; Guan and Liu, 2016; Lee and Walsh, 2016), innovation studies benefited from the development of other fields of research such as sustainability and transition studies (Markard et al., 2012, p. 955). Sustainability and transition studies emphasise S&T as socially embedded processes. That is to say knowledge is intertwined with mental maps, the expectations of consumers and shaped by institutional/regulatory structures and infrastructures (Markard et al., 2012, p. 955). There is little consensus on how to operationalise the approach to sustainability transitions. Several viewpoints co-exist, as well as a broad range of relevant theoretical approaches, encompassing perspectives like evolutionary economic theory (Nelson and Winter, 1982), strategic niche management (Kemp et al., 1998), technological innovation systems (Bergek et al., 2008), multi-level perspective on sociotechnical transitions (Geels, 2011, 2002) or eco-innovation (Andersen, 2008; Kemp, 2010), just to enumerate a few.

Although terminological creativity can be taken as an early indicator of conceptual restlessness, there may be a point where "label proliferation" may hamper progress in a field (Alvarez et al., 2014; Barney, 2003). As Table 6 shows, terms emerging in the literature since the mid-1990s, linking innovation to environmental concerns, have somewhat distinct, yet related, definitions. "Environmental innovation", for example, is characterised as innovation with environmental benefits (van den Bergh et al., 2011; Weber and Hemmelskamp, 2005). By contrast, "Sustainable innovation" is thought of as more rounded innovation, addressing ecological, economic and social concerns, hence being more sensitive to the spatial, temporal and cultural context (Boons et al., 2013) and focusing not only on product and process innovations, but also on organisational models (Charter and Clark, 2007). In turn, "Green innovation" is described in terms of new or improved products and processes, with the aim of fostering environmental sustainability (Cuerva et al., 2014). More recently, "Business model innovation" seems also in line with this semantic field, being defined as innovation in the way organisations create, deliver and capture value, so as to maximise societal and environmental benefits (Bocken et al., 2014).

As for "Eco-innovation" (EI), its initial "end of pipe" focus has recently been broadened in scope. EI is nowadays defined as a way of enabling economic performance that does not hinder sustainable development (i.e. economically, ecologically and socially sustainable performance) and is more positively defined, by the European Commission, as "resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources." (EC, 2011a, p. 2)

	Description	References
Environmental innovation	"innovation can be beneficial to both the innovating firm and the environment".	Weber and Hemmelskamp, 2005, p. 3
Sustainable innovation	"Process where sustainable considerations (environmental, social and financial) are integrated into company systems, from idea generation through to research, development and commercialisation. This applies to products, services and technologies, as well as to new business and organisational models"; also "adoption of new processes and systems at societal level".	Charter and Clarke, 2007, p. 9
	"sustainable innovation brings into focus the relevance of (…) the relationships with other actors (i.e., suppliers and customers)".	Boons et al, 2013, p. 11
Green innovation	"innovations in products, processes or business models lead the company to higher levels of environmental sustainability".	Cuerva et al. 2014, p. 104
Business model innovations for sustainability	Business model innovations for sustainability are defined as: "innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organisation, and its value-network, create, deliver and capture value (i.e. create economic value) or change their value propositions".	Bocken et al. 2014, p. 44
Eco-innovation	"innovation which is fuelled by ecological issues (…)".	Fussler and James, 1996, p. xi
	"develop new ideas, behaviour, products and processes, apply or introduce them, which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets".	Rennings, 2000, p. 322
	"innovation that improves environmental performance (…)".	Carrillo-Hermosilla et al., 2010, p. 1075; 2009, p. 4
	"the creation of new, or significantly improved, products (goods and services), processes, marketing methods, organisational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives".	OECD, 2010a, p. 40
	"any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development".	EC, 2011a, p. 2

Table 6 - The family of "environmentally-friendly" concepts of innovation.

EI is also acknowledged as a way of increasing competitiveness that has positive impacts on the environment and society (OECD, 2009a), and an indispensable condition for sustainability (Aghion et al., 2009; EC, 2011b). In spite of some irreducible variability, some efforts towards simplification and consolidation may be useful here. In the context of this research, EI, taken as a streamlined and all-encompassing term for environmentally-sensitive innovation, will be used preferentially. This term refers to all types of innovation addressing ecological concerns and/or having positive ecological effects (Jabbour et al., 2015). Considering the redirection of innovation studies towards "transformative innovation" (see Schot and Steinmueller, 2016), the overlap between EI and CE may prove to be a fulcrum for realising the potential of a new clean and coherent socio-techno-economic paradigm.

2.4. Untangling and re-focusing "eco-innovation"

For the purposes of policy-making, entrepreneurial decision-making and academic research, a clear definition of EI and its dimensions is helpful. A broad, but applicable, operational definition can be offered here as: new or improved socio-technical solutions that preserve resources, mitigate environmental degradation, and/or allow recovery of value from substances already in use in the economy. This definition (de Jesus and Mendonça in UN, 2015, p. 90) includes a number of critical aspects:

- improved environmental performance (i.e. green innovation);
- market efficient and clean results (i.e. environmental innovation);
- enduring and socially responsible benefits (i.e. sustainable innovation);
- holistic transformation (i.e. business model innovation for sustainability).

EI is understood as a systemic problem-solving tool for enabling a holistic and transformative departure from the current unsustainable state-of-play. As a conceptual backdrop to the discussion of CE this research combines the neo-Schumpeterian systems view with the emerging "transformation turn" in innovation studies (Martin, 2016). This definition provides a robust way of understanding the many different facets of EI, whilst also integrating the many diverse areas of analysis already undertaken on this issue. Drawing on existing EI typologies (OECD, 2010a), inspired by the innovation guidelines of the Oslo Manual (OECD, 2005, 1992), EI is operationally summed up as: *new or improved socio-technical solutions that preserve resources, mitigate environmental degradation and/or allow recovery of value from substances already in use in the economy*.

That is any innovation that: a) has positive environmental impacts, and; b) directly or indirectly avoids natural capital damage, while delivering cost efficiencies, market enhancement, or regulation considerations, and; c) results in new or improved goods and services, technological and non-technological processes, marketing or organisational schemes; d) is incremental or radical, and; e) involves an actor or a plurality of actors.

2.5. Main Conclusions

The overlap between the EI and CE literatures is a fertile ground for fine-tuning the definitional issues that still remain open. Based on the literature, this chapter advanced working definitions of CE and EI. CE can be seen as a state of compatibility between technological and socio-institutional sub-systems that overcome the unresolved mismatches of a take-make-dispose depletion-prone era. As for EI it is defined as a set of technological and non-technological innovations that prevent, mitigate, and allow recovery from environmental damage. EI can be used as a transformative *process* to move away from the *status quo,* to thus create a socio-economic system based on the CE approach. This EI transition towards a CE is both uneven (as some activities or sectors will change sooner than others) and destabilising (as pro-CE factors and actors will encourage others to change too). In other words, EI has the potential to trigger a chain of changes and create localised pressures, thus stimulating complementary adaptations elsewhere, which then come together to form a new socio-techno-economic system. As innovation enabled the development of an industrial, carbon-intensive economy, it is plausible that ("transformative") innovation may now be the vehicle for triggering a new, "green" transition (Schot and Kanger, 2016). Today, it is both topical and urgent to understand how, and by which means, innovation is able to facilitate the emergence of a CE.

CHAPTER 3

EXPLORING THE MEANING AND IMPLICATIONS OF THE ECO-INNOVATION/CIRCULAR ECONOMY CONNECTIONS

In the ongoing sustainability debate, the circular economy (CE) has been steadily gaining ground as a new approach. At the same time, eco-innovation (EI) has been recognised as a key element in carrying out the transition from a linear to a circular system of production and consumption. However, little information can be found concerning whether and how EI can actually facilitate the change to a CE. While extensive literature on EI, and a growing body of research exploring the CE, already exist, there is, as of yet, no comprehensive understanding concerning the connections between these two concepts. Drawing on academic contributions from the fields of EI and CE (detailed in the methodological section 3.2), this chapter seeks to clarify and synthesise findings at the intersection of these two fields (section 3.1). The aim is to review the role of EI at CE's macro, meso, and micro levels; characterise CE-inducing EI in terms of targets, mechanisms and impacts (section 3.3), and provide policy implications structured by EI-CE connections (section 3.4)

3.1.Eco-innovation and the Circular Economy: Linking the concepts

If cheap resources for widening markets supported the 20th century's economic growth, the first decades of the 21st century brought rising price volatility and geo-economic uncertainty (Dobbs et al., 2011). Meanwhile, even if recycling is now seen as indispensable, waste production remains largely unchecked (WWF, 2014). Palliatives may not be enough, as global consumption has been increasing dramatically in the last two centuries and is expected to triple by 2050 (Vanner et al., 2014). New global trends are emerging, such as tighter environmental standards and consumer sensitivity to climate change. In this context, the concept of a new economic model, working in closed-loops, encouraging and encouraged by innovation throughout the whole value chain is advocated as an alternative solution for minimising waste of materials and energy in a world that remains competitive and dynamic, but finite (Potočnik, 2014; UNEP, 2011, 2006).

The EU, since the adoption of the Lisbon Strategy in 2000, has been actively involved in the development and implementation of a "greener" sustainable economy and society, assuming a global leadership role in this regard. Its most recent efforts concerning the promotion of a transition to sustainability have focused on a number of flagship projects and action plans concerning EI (EC, 2011a; EIO, 2013a, 2011), resource efficiency (EC, 2014b, 2011c) and, most recently, the CE (EC, 2015a). The pursuit of a CE is now central within the EU agenda, with the Commission's Circular Economy Action Plan stressing the EU's commitment and support for CE, but also recognising the close connection with innovation, and especially EI (EC, 2017a). It is argued that the CE is contingent "on adopting a systemic approach to eco-innovation that encompasses value and supply chains in their entirety and engages all actors involved in such chains" (EC, 2016a, p. 73).

Transforming production routines and consumption habits through an endless rewiring of loose ends of various activities is a dynamic enterprise (EMF, 2013, 2012). EI is identified as a key way for doing so, through the development of new products and processes based on new technologies, as well as new business models, centred on novel organisational forms and marketing schemes (Tregner-Mlinaric and Repo, 2014). EI-CE connections, the key focus of this study, can thus be explored (see Figure 2).

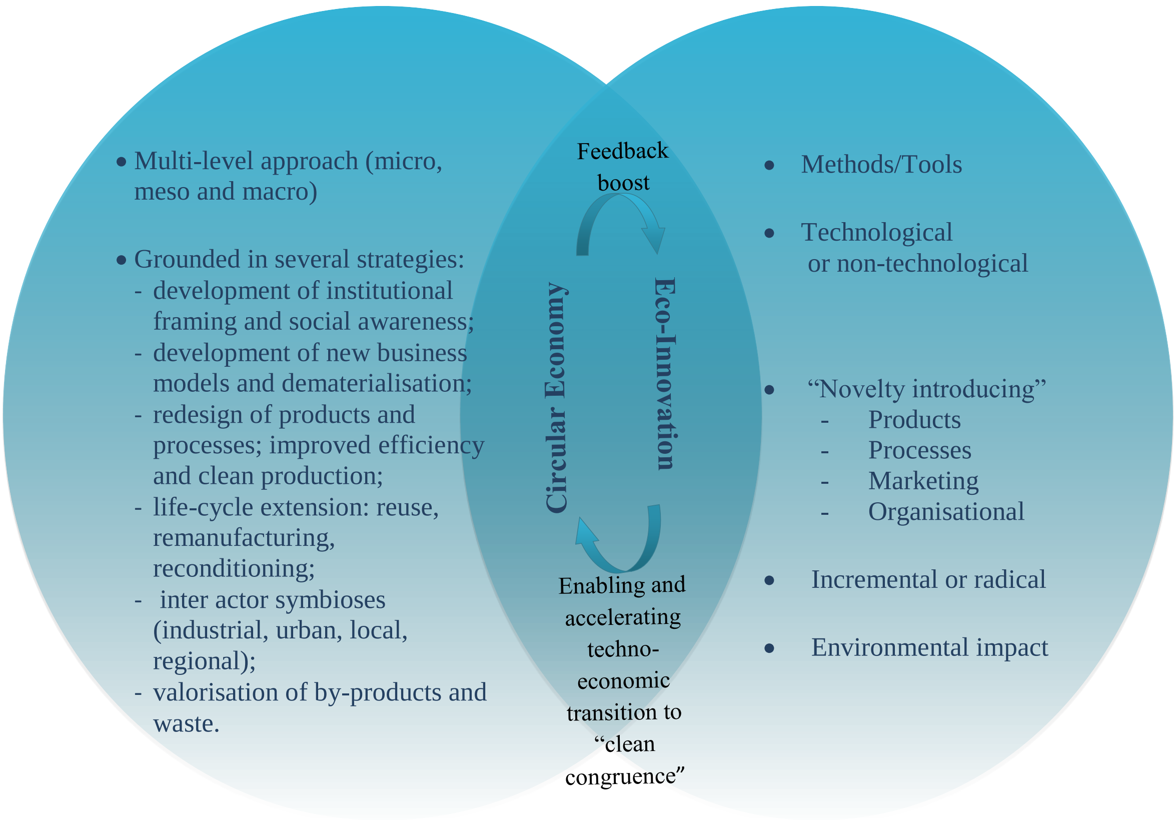

Figure 2 - Relationships between EI and the CE

The connections between these two concepts are, nevertheless, complex. Both still encompass several related terms and have somewhat vague boundaries. While their relation is undeniable, a deeper analysis could make use of the specific aspects already pointed out, namely EI targets, mechanisms and impacts (Figure 3 - horizontal axis) and the micro, meso and macro levels of CE (Figure 3 - vertical axis).

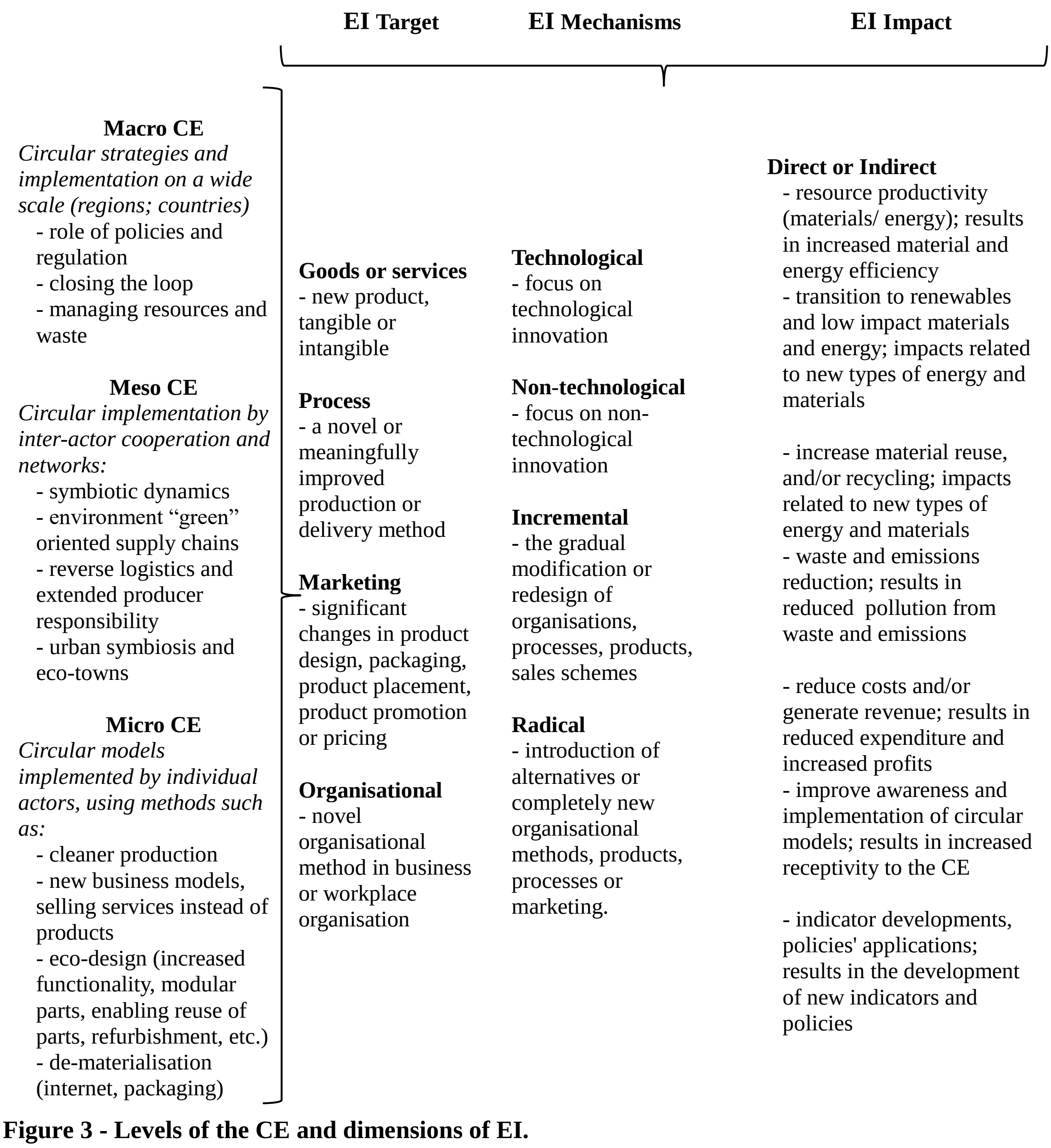

Figure 3 - Levels of the CE and dimensions of EI.
Note: Inspired on Geng et al. (2012); Geng and Doberstein (2008); OECD (2010a); OECD (2005).

The ensuing literature review provides supportive evidence, whilst distilling the practical insights. A deeper understanding of the overlap between EI and the CE may help to articulate how a closed-loop, production-utilisation congruence requires thorough implementation of specific types of change. These self-reinforcing patterns (that can be understood as forms of "clean congruence") can be attained at distinct levels (macro-meso-micro), which may be mapped and monitored as policy and other decision makers seek strategies for transition towards a CE. The generic term of "clean congruence" refers to the process of dealing with mismatches at a variety of levels between ecological and economic sustainability in the context of an emerging (green, innovative) socio-techno-economic paradigm.

3.2. Methodological considerations

A literature review, following and adapting several prior methodological contributions (Bocken et al., 2014; Boons et al., 2011; Castro e Silva and Teixeira, 2011; Silva and Teixeira, 2008), was used to analyse the clusters of ideas broadly understood as EI and the CE. This section makes clear some methodological consideration regarding said analysis.

3.2.1. Data criteria and collection

The methodological path followed is illustrated on Figure 4. Data was obtained from scholarly peer-reviewed journals. A circumscribed corpus was identified by using two of the most widely-used databases of academic journals, namely the Web of Science (WoS) Core Collection[2] and Scopus[3]. Material was identified through a keyword Boolean search on title, abstract, and keywords of articles and reviews, written in English, in the assumption that this would identify all the latest relevant global research. The goal was to ensure that relevant peer-reviewed publications were found. As the interconnections between EI and the CE are still not clearly defined, it was acknowledged, from the onset, that the use of the target terms alone carried a risk of exclusion and bias. As chapter 2 stated, there are several concepts closely connected to

[2] The WoS TM Core Collection is contained within the Web of Knowledge database platform of bibliographic references, produced by the Institute for Scientific Information (ISI), covering over 12,000 of the highest impact journals worldwide in the fields of sciences, social sciences, arts, and humanities, including Open Access journals and over 150,000 conference proceedings, being one of the most generally acknowledged sources of data for bibliometric studies (Franceschet, 2009; Moya-Anegón et al., 2007).

[3] Scopus is the largest abstract and citation database indexing the greatest number of peer-reviewed journals (Falagas et al., 2008), around 21,500, from more than 5,000 international publishers (Elsevier, 2014), having a more European focus (Chappin and Ligtvoet, 2014).

EI and the CE. Which ones should then be chosen as keywords, and which ones excluded?

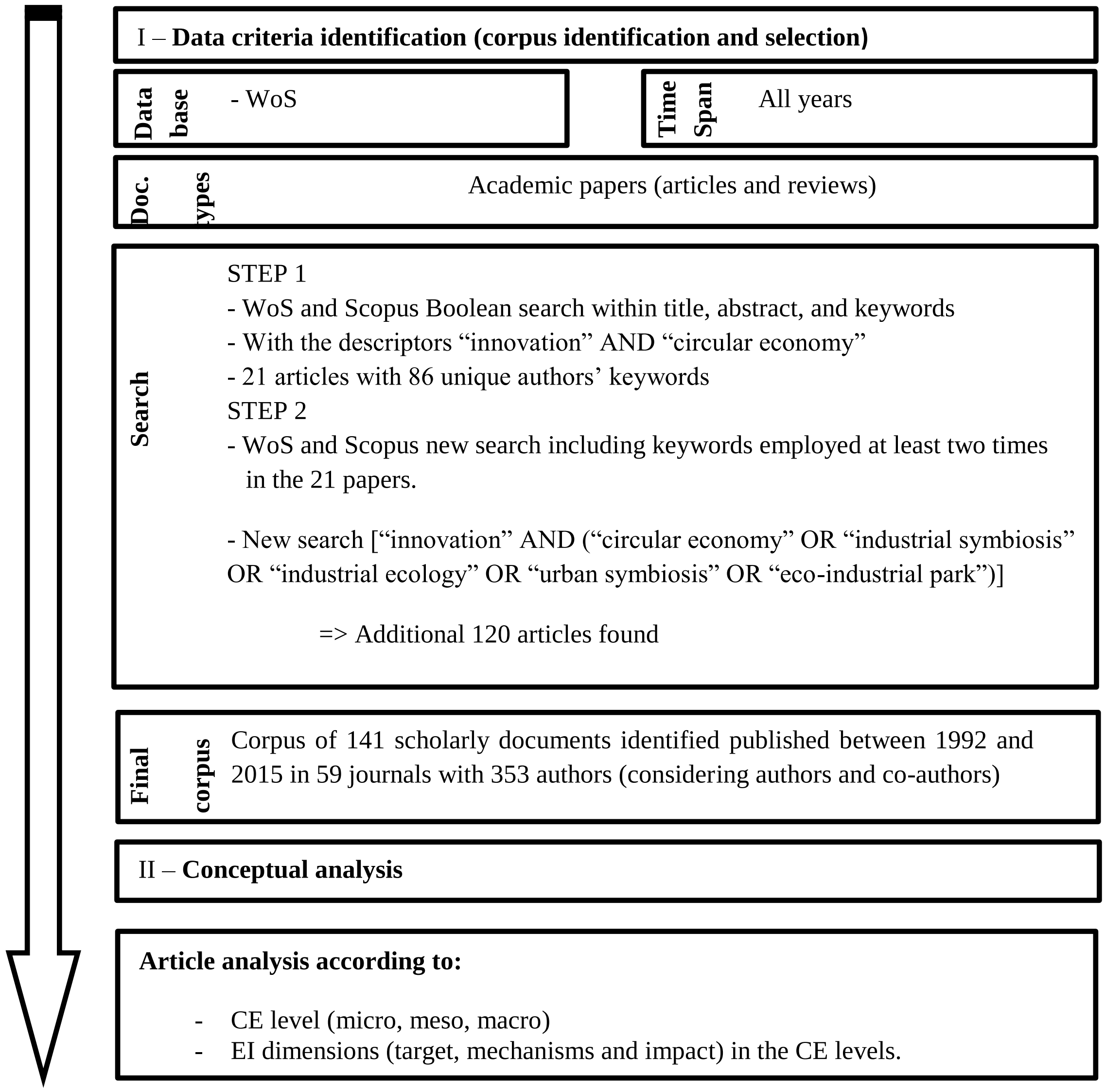

Figure 4 - Layout of the research design.

In an initial exploratory exercise, in order to minimise the biases of subjectively choosing a closely connected concept over another, the first query searched only: “*innovat*” AND (“circular economy” OR “circular-economy” OR “circul* economy*”).[4] This search identified a total of 21 downloadable articles across the two databases (several articles appeared in both databases and were only counted once).

[4] The search was carried out on 27 March 2015, and then updated on 13 November 2015. The Boolean operator * is used to enable the return of expressions that begin with the word truncated by the asterisk.

Although this effort produced a very limited set of results, the articles enabled the identification of 86 unique keywords (provided by the authors of the articles). As keywords contain critical and concise information regarding the substance of each article, they were used as guidance for finding other relevant works. By analysing keywords used at least twice, the descriptors "industrial symbiosis", "industrial ecology", "urban symbiosis" and "eco-industrial park" were highlighted. These new descriptors were then used, in association with "*innov*", resulting in the retrieval of an additional set of documents (120 new articles). A grand total of 141 articles, published between 1992 and 2015, were thus assembled as the final corpus for analysis (detailed references in Appendix 1).

3.2.2. Analysing the articles

Drawing on the propositions underpinning the EI and CE bodies of research (Chapter 2), the articles were read in full, focusing on the identification of EI dimensions (target, mechanisms and impact) and the levels of the CE (micro, meso, macro). These categories (summarised in Figure 3), are used to organise the extraction of meaning and trends from the 141 papers.

Categorisations are not straightforward, and their application requires judgement. Regarding EI impacts, for instance, the available literature stresses the difficulty of outlining and measuring them accurately (OECD, 2010a). As such, inspired by examples identified in the corpus itself, some EI impacts are typified (Table 7). Here too it was necessary to make choices. Although the impacts are normally divided in the literature by their direct or indirect effects, the types identified could often have both effects. For instance, increased reuse and/or recycling of materials has a direct impact, in terms of reducing pollution and waste production, but may also have an indirect impact, in terms of improving awareness and implementation of CE models.

As for the CE, several of the articles could fall under more than one level of "circularity". For example, cleaner production at a company – the micro level –, when addressed from a government perspective (i.e. fostering the implementation of those initiatives), could be seen as macro level (Geng et al., 2010b). Similarly, as regards eco-towns and urban symbiosis, although other articles usually place these at the macro level (Ghisellini et al., 2016), it was here judged to be better to identify these as meso level, emphasising the cooperation between the city and other actors. As such, choices had to be made when allocating articles to a unique category. The overall goal of the analysis, however, is not to gather exhaustive examples, or to carry out a definitive analysis, but rather to convey the core thinking behind the demonstrative cases, and highlight the major patterns that can be gleaned from the literature, so as to enable the emergence of new conclusions regarding the poorly understood connection between EI and the CE. The inescapable degree of subjectivity involved in implementing the survey criteria was not, therefore, viewed as overly problematic.

Direct and indirect impacts
Resource productivity (materials/ energy) - Material and energy efficiency
Transition to renewables and low impact materials and energy - New types of energy sources and materials
Increase material reuse, and/or recycling - Durability and valorisation
Waste/ pollution/ emissions reduction - Lessening of pollution, waste and emissions generation
Reduce costs and or generate revenue - Expenditure reduction or profit generation
Improve awareness and implementation of circular models - Circular models acceptance
Indicator developments, policies' applications -Development of indicators and policies

Table 7 - Key characteristics of EI impacts.

3.3.Eco-innovating towards a circular economy: results of the literature review

In an aggregated overview of the articles it was found that most were published between 2006 and 2015 (83%),[5] which shows that there is a growing interest in these fields (Figure 5). Using the operational definitions, and the proposed analytical framework, the corpus was examined by CE level, focusing on the role of EI. The macro/meso/micro organising principle for unpacking EI-CE connections allowed us to give structure to the findings. The aim was to identify developments in the literature, as well as research gaps and policy prospects.

[5]The search was last updated in September 2015. This can justify the apparent drop in 2015.

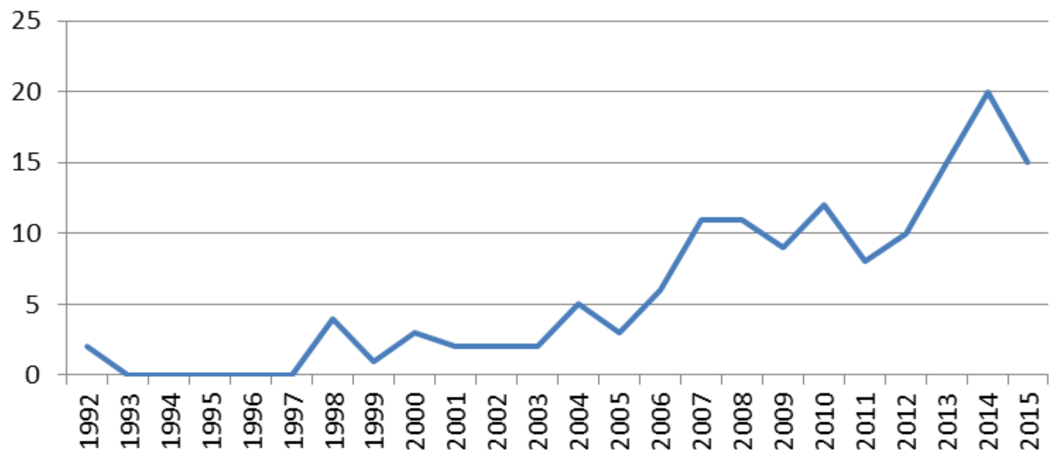

Figure 5 - Number of academic published papers per year.
Note: N=141. Elaborations on the corpus; applies to all tables and figures in the chapter from now on, unless otherwise stated.

3.3.1. Circular Economy at the Macro level

Examining the sub-set of articles categorised at the macro level, four important considerations stand out: 1) the CE emerges as a multidisciplinary, difficult to define, concept; 2) governance and public policies have a central role in supporting and promoting EI and the CE; 3) at the wider national and transnational scales, resource efficiency and waste management are particular concerns; 4) EI appears to be an enabler of the transition to a CE.

CE is indeed characterised as a wide-ranging concept, still rather difficult to define: "circular economy does not have a single definition, it generally stresses closed flows of materials, and increased efficiency in the use of raw materials and energy" (Matus et al., 2012, p. 194). Contributions from several different schools of thought add to its intellectual development, from industrial ecology, systems theory, global environment studies, environmental innovation, spatial planning, societal transitions, ecological modernisation, technology policy, and innovation management.[6] The links of CE to a diverse economics background are also evident, being associated with fields such as evolutionary economics and ecological economics - i.e. heterodox research programmes (del Río et al., 2010; Koenig and Cantlon, 1999; van den Bergh, 2013), as

[6] To enable an easier reading, when there are more than three references together these are gathered in footnotes, here: (Baas and Hjelm, 2015; Bakshi et al., 2015; Cohen, 2006; Deutz, 2009; Huber, 2000; Koenig and Cantlon, 1998; Körhönen, 2008; Körhönen et al., 2004; van den Bergh, 2013).

well as environmental economics - i.e. more mainstream approaches to the environmental agenda (Su et al., 2013).

At this level another issue raised was the important role of governments in: providing context; ensuring coordination; and leading the way in the promotion of new industrialisation models that are more efficient, less polluting and involve less exploitation of resources. Progress in science, technology and innovation is identified as a way for developing countries to advance their overall catch-up process (since they have the potential to leapfrog, at least in the environmental-economic nexus), and also a way for developed countries to increase well-being and reduce vulnerability to resource price shocks (Cheng, 2007; Geng et al., 2012, 2009b). Governmental action is, therefore, considered fundamental in managing "different initiatives, enacting appropriate regulations, stipulating feasible guidelines and standards, providing substantial financial support and carrying out international collaboration" (Geng et al., 2010b, p. 1507). Governmental action emerges as both an instrumental driver, in framing pro-CE behaviour and transition-friendly networking capabilities, as well as a barrier, when failing to "enable" a CE context.[7] Since a CE remains a concept under construction, misunderstandings and misaligned policies are possible. Regulatory frameworks (i.e. taxes and incentives) must provide clear objectives in terms of environmental performance, helping to address market failures and allowing CE initiatives to prosper. At the same time, public agencies play a crucial role in ensuring planning and institutional guidance (for example, infrastructure provision and a conducive legal system), as well as by providing R&D support, enabling information exchange, encouraging the engagement of actors and promoting awareness, e.g. amongst enterprises, universities and wider society (Cheng, 2007; Nguyen and Ye, 2015).

In the promotion of a CE, several countries have already acted at a policy level, promoting legislation with CE effects, for instance the EU action plan for a CE (EC, 2015a). Asian countries have also demonstrated an awareness of the CE agenda, particularly Japan and China. The latter was a pioneer of explicit legislation regarding CE (Dong et al., 2013b), making it a key national policy and a regulatory priority, in

[7] (Andrews and deVault, 2009; Bergquist et al., 2013; Cheng, 2007; Heyes and Kapur, 2011; Yarime, 2007).

particular as a vector for focusing on cleaner production and eco-industrial parks development (the 12th Five-Year Plan, 2011-15).

Emerging policy avenues have underlined the need to move away from the existent resource-based paradigm. As consumption has risen, in both developed and developing countries, recycling and reuse has been identified as vital in closing the loop (Graedel and Cao, 2010). This transformation is considered dependent on innovative technologies, as well as new organisational forms, to manage resources and waste (Geng et al., 2014; Giannetti et al., 2004; Zhijun and Nailing, 2007). Awareness of the intrinsic value of waste and "the extent of knowledge that (…) led to technological innovation for reuse" (Park and Chertow, 2014, p. 47) has become essential. If throughout human history waste has been recognised in a negative sense (associated with unwanted, unusable, worthless materials, lacking economic value or potential), current challenges reinforce the need for a rethink. In a CE waste is meant to be minimised (Köhler et al., 2011; Levänen, 2015) and rather returned as an available resource[8] in a process that is efficiently macro-managed in order to guarantee further community development. The need for novel management practices in the production process is stressed, i.e. production needs to be organised more broadly, so that it transcends the linear input-to-output sequence (Jones et al., 2013).

Technology-driven EI is considered as an enabler of new ways of reusing and recycling substances, giving them other industrial applications (Wen et al., 2007). However, the CE is more than just about re-engineering existing processes (i.e. incremental change of existing components); importantly, it is also about re-wiring (i.e. changing the architecture of) the whole system of supply and demand. More cost-effective, less environmentally-harmful innovations hinge upon the creation of realistic market opportunities (Brils et al., 2014), as well as the design of new processes and products[9], while information and communication technologies are crucial in product/service "dematerialisation", product tractability and performance monitoring (Erdmann and Hilty, 2010; Maurizio Catulli, 2012; Moreno et al., 2011). Given its role in decreasing the environmental impact of economic activities, EI is understood as a major avenue for introducing systemic novelty in the transition towards more sustainable and viable countries, within an integrated vision of society, economy and

[8] (Birat, 2015; Corder et al., 2015; Fichter and Hintemann, 2014; Muñoz et al., 2008).
[9] (Anastas and Lankey, 2000; Barberio et al., 2010; Fiksel, 2002; Grundmann et al., 2013; Jin et al., 2004; Matus et al., 2012; Ogunseitan, 2007; Reh, 2013; Thomas et al., 2003; Wen et al., 2007).

environment.[10] Overall, process and organisational innovations are the types of EI more emphasised at the macro level (Figure 6). Technological EI emerges as critical, mostly in the form of incremental mechanisms based on the redesign of existing products and production methods, focusing particularly on increasing resource productivity.

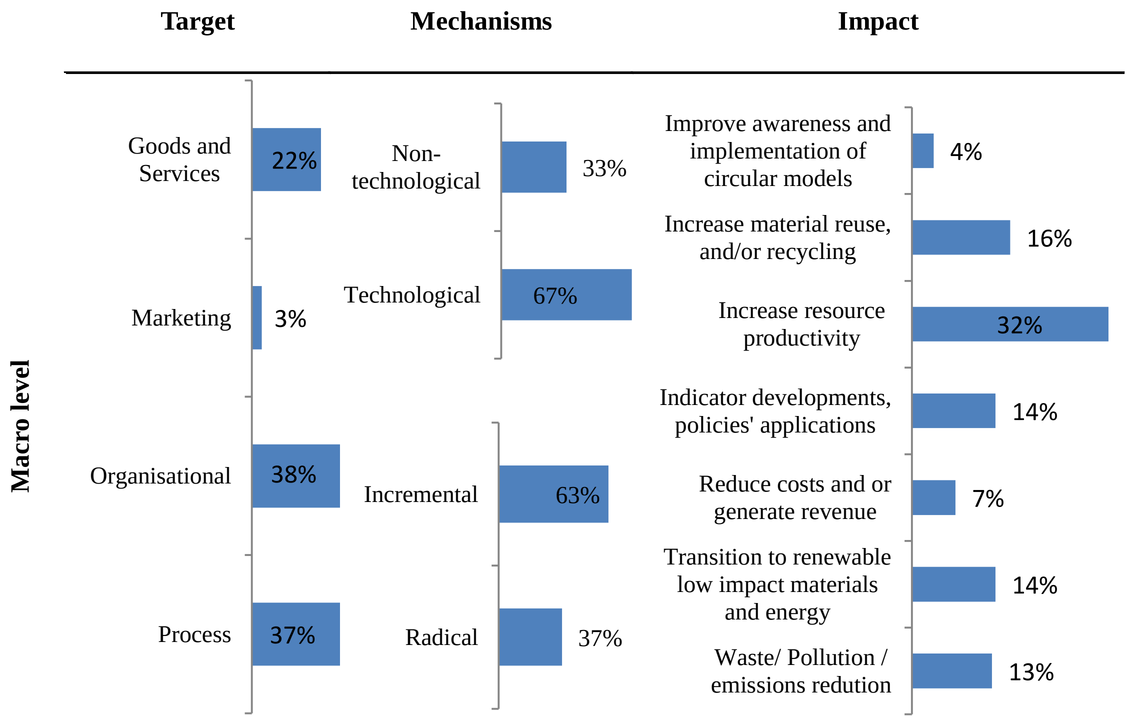

Figure 6 - EI Target, Mechanism and Impact at the CE Macro level, analysis of the corpus.
Note: N=80

Macro-level "circular" EI, however, is also characterised by mixed environmental results (Vivanco et al., 2014). There are rebound effects. For instance, low carbon technologies use rare materials, such as lithium. The availability of these materials can become an environmental and procurement problem for nations and regions. With regard to the United Kingdom (UK) electric vehicles market, Busch et al. (2014) provide an example that material flows should be holistically managed so as to avoid constraining the long-term potential for improving the reuse, re-manufacture and recycling of the materials involved. EI is also hampered by: high initial costs (Busch et al., 2014; Mirabella et al., 2014; Reh, 2013); limited public and business awareness

[10] (Carrillo-Hermosilla et al., 2010; Cheng, 2007; del Río et al., 2010; Ganapathy et al., 2014; Tombesi, 2006).

(Heiskanen and Lovio, 2010; Jones et al., 2013; Riding et al., 2015); and potentially, regulatory mismatches and conflicting interests between economic and environmental agendas.[11]

Similarly, and in spite of playing an important role, S&T *per se* (i.e. EI disconnected from the broader context) are not considered sufficient conditions for the transition to new paradigms. Whereas technological innovation is believed essential for boosting resource efficiency, as well as production and waste minimisation, non-technological innovation is still deemed essential for "selling" new products and services (Dewick et al., 2007). A systemic approach to change, addressing the societal and contextual settings, is thus highlighted as crucial (Huesemann and Huesemann, 2007). More than revolutionising the existing economic structure, the EI mechanisms stressed at the macro level focus on evolutionary changes towards a "clean congruence", based on incremental redesign and modification of existing systems spanning different sectors and value chains. This seems compatible with the development phase of a CE when several products, industries and business models are emerging (Blowfield and Johnson, 2013). Within this transition, the emergence of new technologies is complementary to wider social, economic and legal/political developments, including increased public awareness, new regulations, and changes in market supply and demand. At a macro level, this phase can be characterised as a temporary period of reorganisation and reconfiguration of a country's socio-techno-economic systems, involving all societal actors.

3.3.2. Circular Economy at the Meso level

The meso level addresses networks and interactions. Moreover, CE's own nature, as an integrative multi-actor approach, points to the importance of networks for: building capacity; increasing cooperation in research and investment; sharing materials and by-products, and; managing common utilities and infrastructures. The establishment of these networks is generally motivated by agents interested in cost reduction, economies of scale, and lesser exposure to resource price volatility, and is a determining factor in the implementation of a truly CE. At a meso level, the CE links with several concepts related to the establishment of cooperation and alliances, from which the

[11] (Busch et al., 2014; Jones et al., 2013; Matus et al., 2012; Riding et al., 2015).

corpus emphasises those in or within: industry (e.g. industrial symbiosis and eco-industrial parks); value chains (e.g. sustainable, environmental and "green" supply chains, and extended producer responsibility); local-government initiatives (e.g. eco-towns and urban symbiosis). The emphasis given to these concepts, rather than others, may be related to the scope of the corpus itself, covering largely European and Asian examples.

Industrial symbiosis is based on an "industrial systems integration" approach (Geng et al., 2014). It focuses on the potential of networks for exchanging materials and by-products, as well as for sharing management of common utilities and infrastructure for water, energy and waste, between several actors (van Berkel et al., 2009). The sharing of services, such as transportation and infrastructure, and the brokering of by-products (so that the waste from one industry waste becomes the input of another), results in pollution mitigation, decreased use of materials and energy, and cost reductions, and thus creates both economic and environmental benefits. Kalundborg in Denmark is considered the pioneer model and inspiration, but there are already several other examples of industrial symbiosis.[12] Linked with industrial symbiosis, the notion of an eco-industrial park is also important. Eco-industrial parks retain the positive externalities of industrial parks, which arise from: businesses being located close together; economies of scale; inter-firm communication; centralised transportation; and waste disposal infrastructure. However, they also add the potential for symbiosis regarding ecological considerations, related to minimising negative impacts in local resource depletion and pollution. In spite of geographical peculiarities (given that the definition and implementation of industrial symbiosis and eco-industrial parks can differ from country to country) (Boons et al., 2011) and varying stages of development (Chertow and Ehrenfeld, 2012), eco-industrial parks have been found to foster symbiotic networks of cooperation between enterprises (Yu et al., 2015), thus actively promoting the CE at an industrial level (Zhu et al., 2015). For instance, at TEDA – Tianjin Economic-Technological Development Area (China) – the integration of the regional water cycle system provided recycled water to all of the area's users, demonstrating the potential of symbiotic relationships within the eco-industrial park (Yu et al., 2014). EI is considered essential in the development of eco-industrial parks and industrial symbiosis, whilst, at the same time, these concepts have a role in the

[12] (Chertow and Ehrenfeld, 2012; Geng et al., 2009a; Liu et al., 2012; Mathews and Tan, 2011; Park et al., 2008; Patnaik and Poyyamoli, 2015; Shi et al., 2010; Shi and Yu, 2014; Yu et al., 2014; Zhu et al., 2015).

development of institutional, technological and business model innovations (Shi and Yu, 2014).

As for "sustainable supply chain management" (Gupta and Palsule-Desai, 2011; Ji et al., 2014; Zhu et al., 2010), "green supply chain management" (Mirhedayatian et al., 2014; Park et al., 2010), "closed-loop supply chain management" (Guide and Van Wassenhove, 2009), "extended supply chain" (Zhu and Geng, 2013), and "extended producer responsibility" (Chen and Sheu, 2013; Lai et al., 2014), these concepts all focus on improving a product life-cycle via its supply chain. The objective is to reduce costs by sustainably managing the life-cycle of products from conception (e.g. less use of materials and energy in production, packaging and delivery) to end-of-life (e.g. reuse, reduced waste, creating recovery networks, etc.). This involves the responsible incorporation of environmental considerations into supply chains from the outset, and the promotion of cooperation between companies, suppliers and customers, to "close the loop". The conversion of existing supply chains is supported by a set of technological developments that enhance resource efficiency, reuse and recycle, as well as organisational innovation leading to new distribution, collection and business models (Rashid et al., 2013).

Considering that urban growth is accelerating, especially in developing countries, and that cities play a role as both industrial and population centres, an integrated approach to cities is necessary for designing new ways of tackling environmental problems and mitigating pollution (Dienst et al., 2013). In China, in particular, the problems of the so-called "resource-based cities" (i.e. cities primarily orientated towards extractive and/or resource-intensive industries) have drawn attention given the importance of integrative strategies for moving towards more "circular" cities (Dong et al., 2013a). In this regard, the concepts of urban symbiosis and eco-towns have extended the network rationale to urban actors. This is an integrated view of urban infrastructure, maximising benefits arising from the interrelation between the city and its industrial context, as well as the possibilities within the city itself for fully capitalising on reinforcing infrastructural use, rather than duplicating resources[13]. In this domain, an innovation-friendly environment, as well as efforts from several actors (including governments and industries), are considered essential in the development of

[13] (Chen et al., 2012; Dong et al., 2014, 2013a; Geng et al., 2010a; Niza et al., 2009; van Berkel et al., 2009).

low-carbon cities (Dong et al., 2013a). Innovation in these processes involves enhancing the ability to develop both "software projects" (e.g. town planning, community recycling, and outreach activities) and "hardware projects" (e.g. innovative recycling facilities and associated infrastructure) (Chen et al., 2012).

Closing the loop at the meso level therefore seems dominated by inter- and cross-sectoral pooling of infrastructural resources (i.e. eliminating wastage in overhead capital), as well as by the maximisation of synergies across different value chains (i.e. interactions between production systems and agents). Promoting cooperation and interrelations between geographically-close actors, companies and organisations, is considered an effective way of achieving a more circular system, with better use/reuse of resources. It seems interesting to note that, in regard to these relationships, the role of business associations is never mentioned in the corpus, while one could expect these and other entities (such as consumer organisations) to play a role in bringing companies together, so as to increase collective environmental efficiency.[14]

Overall, EI at the meso level is described as a facilitator of sectoral or regional systemic integration, enabling new ways of sharing services, utilities and by-products among diverse industrial processes or actors, which in turn provides new ways of promoting cooperation.[15] Green and transformative innovation is key for engaging in financial engineering (i.e. responding to high initial costs and capital investments), as well as for identifying symbiotic links between organisations and sectors (i.e. synergies), and for addressing technical issues such as solid waste, air pollution, water contamination and noise pollution (i.e. bottlenecks).[16]

At this level the literature points to the importance of this green and transformative innovation in attaining a "clean congruence" mostly based on the organisational dimension, on incremental mechanisms (redesign of organisations and processes is particularly stressed in the articles) and on targeting resource efficiency, material reuse and recycling (Figure 7). The transition toward CE seems therefore

[14] The general role of such intermediate associations in the innovation process has been emphasised in a small amount of relevant literature (see, e.g., Dalziel, 2006; and Watkins et al., 2015).

[15] (Baas, 2011; Bristow and Wells, 2005; Desrochers, 2004; Dong et al., 2014; Gupta and Palsule-Desai, 2011; Killerby et al., 2007a; Lombardi and Laybourn, 2012, 2012; Mirata and Emtairah, 2005; Paquin and Howard-Grenville, 2012; Park et al., 2008; Ruiz Puente et al., 2015; Short et al., 2014; Simboli et al., 2014; Watkins et al., 2013; Yu et al., 2015a; Zhu et al., 2010).

[16] (Cecelja et al., 2015; Geng et al., 2009a; Hewes and Lyons, 2008; Liu et al., 2012; Mathews and Tan, 2011; Park et al., 2008, 2008; Patnaik and Poyyamoli, 2015; Raafat et al., 2012, 2013; Shi et al., 2010; Shi and Yu, 2014; Sterr and Ott, 2004; Van Berkel et al., 2009; Yu et al., 2014; Zhu et al., 2015).

plough on “green collective innovation” trajectories as a way to achieve “clean congruence” at the meso level.

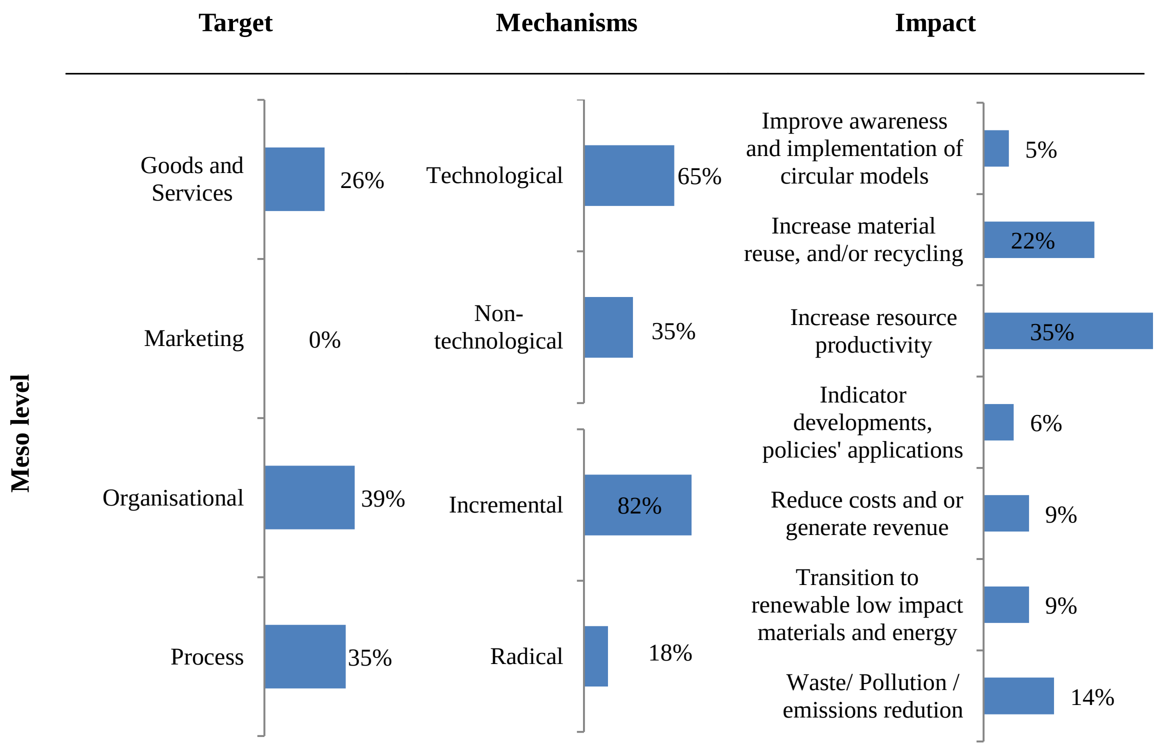

Figure 7 - EI Target, Mechanism and Impact at the CE Meso level, analysis of the corpus.
Note: N=43

3.3.3. Circular Economy at the Micro level

The micro level focuses on specific agents’ capabilities and involvement in CE. It comprises, nevertheless, the smallest part of the corpus, which was a surprise. Although this result could indicate an area of research that is still on its way to maturity, it may also be a sign of a methodological shortcoming. First, it may be that the most appropriate keywords for the micro level were not used; second, and more important, it may be that innovation at this level is very specific and unlikely to be published within scientific articles (for instance, patent data could be more revealing in this respect, something interesting mentioned but not pursued in de Jesus and Mendonça in UN, 2015). Within the corpus, this body of work focuses particularly on cleaner production, eco-efficiency, eco-design and new business models.

Cleaner production emphasises the application of processes, technologies and practices for minimising resource and energy consumption, as well as pollution, in order to accomplish a better overall efficiency within the organisation (Geng et al., 2010b). It includes green design as well as the introduction of clean energy and waste management technologies (Basu and van Zyl, 2006). Other practices such as eco-efficiency (i.e. production of goods or services with fewer resources and waste) and eco-design (i.e. products' design with environmental considerations) similarly aim to develop environmental friendly (or neutral) products throughout their whole life-cycle, thus ensuring energy savings and pollution reduction.[17] The literature cites practical examples ranging from the conservation of resources (Silva et al., 2015), to product design focusing on life-cycle aspects regarding materials usage, processing and maintenance, as well as communication with end-users (Sanyé-Mengual et al., 2014).

New business models based on leasing, rental and "sharing" services, also emerge in this literature, focusing on the replacement of capital ownership and proprietary models. In areas as diverse as housing, transportation and communication, these business models promise more efficient use of resources, extended lifespan of products, and greater reuse of materials at the end-of-life phase (Albu, 2011; Short et al., 2014).

At the micro level, the EI of goods and services is particularly stressed, especially in an incremental mode, in terms of both increasing resource efficiency (Adams and Ghaly, 2007) and eco-design (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2014). Nonetheless, radical alterations are also believed to be necessary as the transition to new sustainable ways of living implies the genuine transformation of the *status quo* (Figure 8).

Technological EI mechanisms are established as tools for addressing bottlenecks in product durability and quality, in designing goods with longer usability spans, and addressing problems of decreasing efficiency over time (Adams and Ghaly, 2007; Mattinen et al., 2015). Designing optimal life cycle scenarios, for products that are intended to be rented and restored numerous times, requires an in-depth knowledge of durability and the replacement schedule of parts. However, it also creates the possibility of constant upgrades (Bakker et al., 2014). Alternative, less expensive ways of reusing and re-manufacturing products are indispensable, since the costs of re-manufacturing are still often higher than the costs of production using virgin materials. Likewise, new

[17] (Collado-Ruiz and Ostad-Ahmad-Ghorabi, 2013; Matos and Hall, 2007; Mattinen et al., 2015; Mont, 2008; Sanyé-Mengual et al., 2014).

ways of limiting the extra (economic and environmental) transportation costs involved in product reuse and re-manufacturing, are essential in order to make these activities more viable (Mont, 2008). But, even if the technology already exists, other kind of innovations may be needed to overcome several reasons that often prevent more sustainable designs. Consumers are still mostly unaware of the choices available (Finster et al., 2001; Graedel and Allenby, 1995). The lack of transparency and credibility coming from dissatisfaction with empty greenwashing rhetoric also hampers the development of "green markets" and the willingness of customers to pay for "green" goods and services (Lemke and Luzio, 2014).

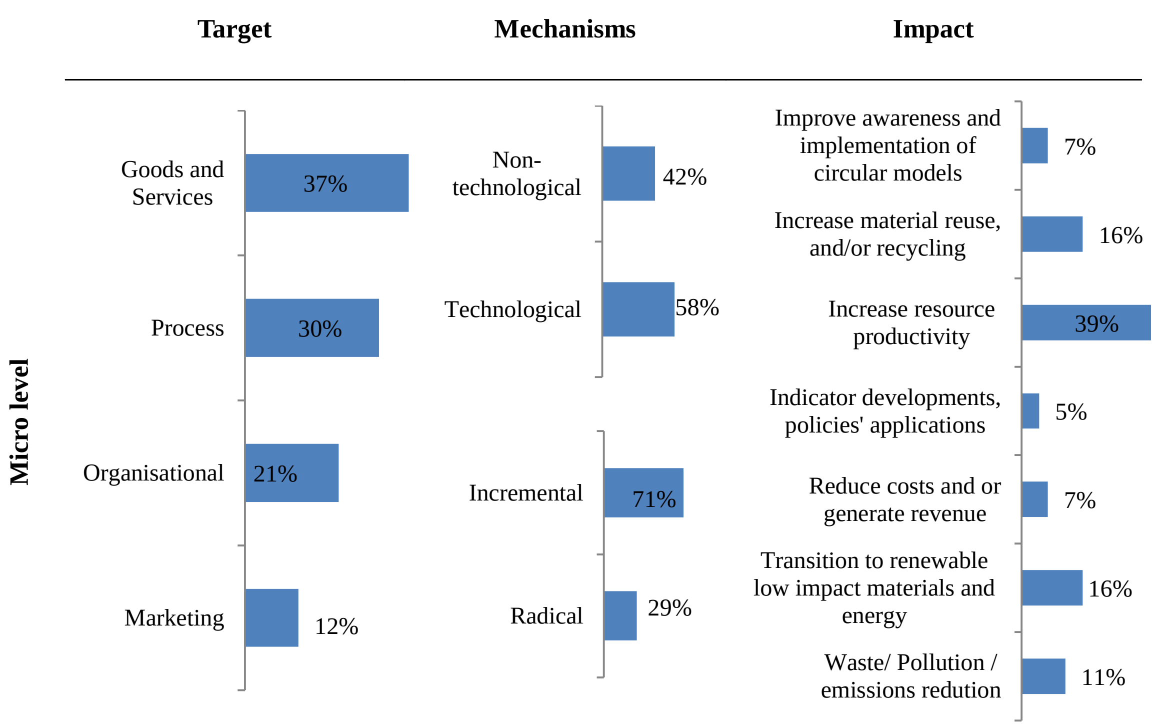

Figure 8 - EI Target, Mechanism and impact at the CE Micro level, analysis of the corpus.
Note: N=18

Non-technological EI, promoting new organisational models may support new schemes for increasing product use intensity through sharing and pooling. At the same time, marketing innovations can enable new ways of distribution, usage and perception for products and services - e.g. monthly payments for the use of refrigerators, washing machines, concrete mixers, and other tools such as drills, saws, hammers etc. (Bakker et al., 2014; Ceschin, 2013; Mont, 2008). These softer type of innovation trends may create incentives for producers to: develop longer-lasting products; replace existing products with more efficient models; and even to upgrade already existing products when new technology becomes available (Mont, 2008). The role of marketing innovation is rather unexplored in the corpus. Similarly, the role of consumers as innovative agents is also not much addressed. This seems paradoxical, since consumers are an integral part of a CE, not only as demand-side actors, but also as an active part of global supply chains themselves.[18] Hence, "dynamic CE business models" seem to be of the essence at the micro-level as a ways to operationalise "clean congruence" and enable transition.

3.3.4. Clearing the ground for "clean congruence": Exploring the meaning and implication of Eco-Innovation/Circular Economy connections

The assembled corpus of articles enables some considerations about the main objectives of this chapter: 1) to review and assess the relation between EI and CE's various levels, and; 2) to identify the types of EI which are most influential in driving the transition to a CE.

First, the definitional challenge is not a minor one. The CE concept suffers from vague boundaries and it includes inputs from numerous schools of thought (Matus et al., 2012). Several slightly different definitions, linking innovation to environmental questions, have also been proposed in the last few decades (Carrillo-Hermosilla et al., 2010). Although the latitude still present in the studies on EI and CE enables the integration of several strategies and perspectives under increasingly used labels, it may hinder their development and hollow out their meaning. Tentative definitions of CE and EI are thus required, which aid the development and use of both concepts; a need we addressed in Chapter 2 by proposing working definitions for both CE and EI and that was furthered developed by this present analysis.

As a broad framework, the relationship between CE and the notion of innovation is still not obvious. CE is an integrative multi-actor approach in which EI (technological and non-technological based) is a tool in the transition towards a cleaner form of "congruence" bringing about a new "socio-techno-economic paradigm" (in the sense of Freeman and Louçã, 2001). Some authors focus on CE strategies as drivers for EI: e.g.

[18] The work on user-driven innovation is very relevant here (see, e,g. Von Hippel, 2005), and could have many applications in the area of EI and the CE.

as a "leading principle for eco-innovation, aiming at 'zero waste' society and economy" (Mirabella et al., 2014, p. 29). However, other authors highlight the causal role of EI within the CE; e.g. "the capacity of eco-innovations to provide new business opportunities and contribute to a transformation towards a sustainable society" (Carrillo-Hermosilla et al., 2010, p. 102).

The inherent relationship between these concepts appears in all the CE levels considered, which were taken as pathways or trajectories towards achieving "clean congruence" (introduced here as a bridging concept between EI and CE literatures). Moreover, the disaggregation by CE level enabled a more thorough and deeper analysis of the main features of EI. At a macro level, governance has a central role in providing context (Cheng, 2007; Geng et al., 2012, 2010b). By promoting EI-led CE policies related to waste management, infrastructure availability, S&T improvements and public awareness, the government can be an inspiring actor. Governments may also have a coordination role in the movement towards a "clean congruence" at cross-sectoral and cross-regional levels; i.e. by avoiding wasteful lock-ins and mismatches that may lead to system failures and barriers to transition along broadly interdependent constituencies and value chains. At this level EI refers to the broad self-reinforcing combinations of socio-technological coalescing changes (i.e. "clean congruence") that allow transition to a CE to take place.

At the meso level, CE is considered to be contingent on systemic or transformative EI enabling new ways of "green collective innovation". That is, innovation that is based on multi-actor and multi-expertise comprehensive technological and non-technological (i.e. organisational and process) change. The latter involves creating new ways of sharing services, utilities and by-products among diverse industrial processes or actors, i.e. providing new ways to promote cooperation. This level highlights the importance of public policies and new ways of boosting cooperation between enterprises and public actors, promoting symbiotic links, addressing technical issues and overcoming institutional barriers (Boons et al., 2011; Cecelja et al., 2015; Raafat et al., 2013).

At a micro level, business strategies range from internal actions of cleaner production (in energy and materials efficiency) to the development of new, more circular business models (i.e. service-based user-producer relationships). At this level, the replacement of the "take-make-dispose" business model implies a greater emphasis on new products, servicing, resource pooling and marketing concepts with EI as a tool to address bottlenecks in product durability and quality, in designing efficient products and “dynamic CE business models”. The sharing of business models and resource pooling schemes are emphasised, as they are especially dependent on pricing innovations and networking-empowered behaviours (Albu, 2011; Short et al., 2014). However, the role of users and citizens at large, so essential in a paradigm shift, is not yet really addressed in the corpus. This may be related to the fact that, in spite of being essential for “circularity” efforts, these issues are seen as too narrow to be called “circular” *per se*. Research at the micro level is also constrained by the fact that the application of the notion of what a CE-based business concept can mean is still under-developed and in a state of flux with limited and only very recent research in the matter (Bocken et al., 2018; Heyes et al., 2018; Stål and Corvellec, 2018; Urbinati et al., 2017).

Finally, regarding the most influential types of EI driving the transition to a CE, organisational and process EI seem generally well developed (especially at the macro and meso levels), whereas references to marketing innovations are scarce. Regarding EI mechanisms, even if authors do reiterate the need for more radical approaches, incremental EI is still predominant. Technological EI, in particular, is considered to be an enabler of change, and essential in the creation of a CE even if the transition is acknowledged to require more than just S&T.

3.4. Key implications of the Eco-Innovation/Circular Economy connections

The review points towards some key themes and main links between EI and CE, which helps to outline broad influential types of EI within specific levels of the CE. These intersections in turn allow a better understanding on how processes of innovation shape transition to a CE and inspire some preliminary considerations regarding policy and business implications. In particular, constructs such as EI-dimensions and CE-levels were applied to outline how current research is pointing to pockets of “clean congruence”, which in turn may provide guidance to policy (summarised in Table 8).

	Key features from the EI-CE literature	EI role	Major types of CE-inducing EI	Policy and business implications	Examples in the corpus
Macro	At a macro level, EI refers to the broad self-reinforcing combinations of socio-technological coalescing changes (i.e. "clean congruence") that allow transition to a CE to take place.	EI mechanisms focus on evolutionary mutations towards overall "*clean congruence*". EI's role as decreasing the environmental impact of economic activities, introducing all-round novelty in the transition towards more sustainable, and integrating vision of society, economy and environment.	Target/Type: -Organisational Mechanism: -Technological	The importance of explicit public policies and new ways of streamlining cooperation between the public and private sectors. Public agencies have a crucial role in planning, providing institutional standards and guidance (infrastructures provision/ conducive legal system). Pro-CE innovation policy is to provide R&D support, but also should facilitate peer-to-peer information exchange.	Carrillo-Hermosilla et al., 2010; Cheng, 2007; del Río et al., 2010; Geng and Doberstein, 2008
Meso	At a meso level, innovativeness for circularity is a distributed and systemic process, where the potential for synergies within value chains and territories are ripe.	EI as a facilitator of systemic integration, enabling new ways of *"green collective innovation"* such as sharing services and other schemes for maximising the value of common resources. EI is a way to re-direct and re-employ by-products among diverse industrial processes or actors	Target/Type: -Organisational Mechanism: -Technological	Promoting the cooperation and interrelation of geographically close companies and organisations is considered to be an effective way of achieving a more circular system, with better use of energy, materials and resources. Strengthened cooperation between actors, and resulting synergies, limits exposure to resource price volatility, reducing costs and minimising the use of non-recyclable materials.	Gupta and Palsule-Desai, 2011; Lombardi and Laybourn, 2012; Ruiz Puente et al., 2015; Watkins et al., 2013; Zhu et al., 2010
Micro	At a micro level, the replacement of the "take-make-dispose" business model implies a greater emphasis on new products, servicing, resource pooling and marketing concepts.	EI as a tool to address bottlenecks in product durability and quality, in designing efficient products and "*dynamic CE business models*".	Target/Type: - Goods and services Mechanism: -Technological	Government role is key regarding the creation of a CE, ensuring adequate regulatory frameworks, and encouraging the awareness of actors and social participation. CE considerations may prove to be an opportunity for positive business differentiation, the development of new CE-friendly business models, and increasing resource efficiency.	Albu, 2011; Bakker et al., 2014; Mont, 2008; Sanyé-Mengual et al., 2014

Table 8 - **Main features from the EI-CE literature, including "pro"-CE EI characteristics, types, and policy and business implications, by CE level.**

Regarding policy, the link between the CE and EI has been most explicitly addressed in recent years by the EU. Increased connections between the two concepts were apparent in the recent EU Action Plan for the Circular Economy (EC, 2015a), following the prior resource efficiency agenda (EC, 2011c), as well as in the Eco-Innovation Action Plan (EC, 2011a). Moreover, policy measures related to regulatory and economic instruments are now closer to the policy implications identified in the corpus. These have been emerging in some EU countries, especially concerning research, education and networking. Even if those efforts are not yet widely disseminated, the examples already in place constitute interesting opportunities for acquiring information about the practical application of pro-CE policy at the national and local levels, whilst also highlighting the differences between actors (EIO, 2016). Examples and characteristics, compiled in Table 8 are not intended to be exhaustive but rather a testimony of the most "real world" relevance features identified in the corpus. It should be stressed that CE-inducing EI policy and business strategy constitute a fertile ground to be investigated in more depth in the future.

3.5.Main Conclusions

What is the role of innovation in the transition towards a sustainable socio-techno-economic paradigm? This chapter tried to address that question by focusing on the ways EI promotes a CE. To clarify the CE-EI link, a corpus of specialised academic peer-reviewed journal articles was identified and reviewed seeking to illuminate the *dimensions* that are more instrumental in achieving a CE at a variety of *levels*. Regarding the connection between the concepts, the creation of a CE seems to be contingent on a process based on cooperation and multi-actor "systemic" integration, with EI emerging as a pathway for achieving that. The EI-CE research shows the importance of what has been emphasised generally as "clean congruence" at the macro-level, as "green collective innovation" at the meso level and "dynamic CE business models" at the micro level. The methodological constraints of "meta" studies are the most relevant shortcomings of this chapter, particularly related to randomisation and the representativeness of the sample. A literature review using bibliometric considerations implies inherent biases linked with keyword definitions and the limited number of sources (Li and Zhao, 2015). The identification of search terms carried implicit risks of exclusion and biases. For instance, the predominance of macro and meso perspectives in the corpus may be attributable to biases in the initial choice of keywords. However, it may also be due to still-evolving definitions of CE being mostly focused, so far, on the macro level. Also, this chapter did not aim to exhaustively collect examples, but rather to express the core thinking behind the literature, so as to enable the emergence of new conclusions regarding the connection between CE and EI. Nonetheless, the methodological and database limitations may still be alleviated in future, by expanding the knowledge base from which lessons are drawn. For instance, this chapter did not collect material from books or reports in the assumption that journal articles are usually the preferred means for academics and practitioners to publish their newest research (Chappin and Ligtvoet, 2014; Linnenluecke and Griffiths, 2013; Markard et al., 2012). The findings could nevertheless benefit from contextualisation using these wider sources of data, particularly considering recent vibrant CE agendas in several organisations.

CHAPTER 4

DRIVERS AND BARRIERS IN THE ECO-INNOVATION ROAD TO THE CIRCULAR ECONOMY

The aim of this chapter is to understand which drivers and barriers exist in the development of a circular economy (CE). Specifically, the focus is on the eco-innovation (EI) pathway towards a CE, trying to coordinate available but fragmented findings regarding how "transformative innovation" can foster this transition while removing obstacles to sustainability. Adding non-academic literature to the previously analysed academic corpus, this chapter offers a framework for analysis, as well as an evidence-based survey of the challenges posed to a green structural change of the economy. The combination of the innovation systems' view with the more recent "transformation turn" in innovation studies may therefore provide an appropriate perspective for understanding the transition to a CE.

Next sections will consequently focus on the identification of an analytical framework for an appreciation of both the dynamics and the inertia of the CE (4.1), considering methodological choices and limitations (4.2) to present results regarding the identification of drivers and barriers to a CE, as well as the role of EI in this transition (sections 4.3 and 4.4).

4.1.Focusing on the drivers of, and barriers to, a Circular Economy

Considerable research exists regarding progress towards a CE in countries, sectors and firms (Böttcher and Müller, 2013; Cuerva et al., 2014; Geng et al., 2009b; Ilić and Nikolić, 2016; Zhu and Geng, 2013). Specifically concerning barriers to implementing the CE, a report for Chatham House (Preston, 2012) identified the following: high up-front costs; complex international supply chains; resource-intensive infrastructure lock-ins; failures in company cooperation; lack of consumer enthusiasm, and; limited dissemination of innovation, across both emerging economies and developed countries. In other reports, concerning the potential of the CE, and policy options, Vanner et al. (2014) surveyed the available literature and analysed the fourteen most relevant studies. They identified a number of factors: insufficient investment in technology; economic signals that do not encourage efficient resource use, pollution mitigation or innovation; minor consumer and business acceptance; lack of awareness and information; and limited sustainable public incentives. Concerning the CE in small and medium enterprises (SME) Rizos et al. (2015) also used a literature review[19] and explored two case studies.[20] He listed six main barriers for the development of a CE, namely: environmental culture; financial barriers; limited government support; lack of effective legislation; information deficits; administrative burdens; and relatively low technical skills.

In spite of increasing efforts, there is still a need for a thorough identification of the conditions required for a CE, especially when the concept intersects with EI (EIO, 2016). To advance the research agenda on the CE, this chapter carries out a systematic exploration of both drivers and barriers, recycling multiple sources of literature input. Likewise, an innovation perspective on CE mechanisms is advanced, by analysing the role of technological and non-technological factors in the creation of a new, circular, socio-techno-economic paradigm. Such a diagnosis can support policy-making, by moving beyond the linear-industrial model.

Innovation is a splintered phenomenon. As Stoneman (2010, 2009) points out, economics typically focuses on *hard* types of innovation, such as R&D-driven products, or cost-cutting processes. Yet *soft* types of innovation, concerned with changes in cultural and organisational artefacts, such as symbols and conventions, are more widespread than previously thought (see Mendonça, 2014). The International Relations scholar Joseph Nye (1990) has applied such hard/soft heuristics (probably deriving such terminology from the hardware/software distinction). In this context, *hard power* refers to the ability to force change (through technical or economic means) while *soft power* is associated with the ability to bring about change by attracting others through values and institutional practices that shape their attitudes and preferences. This conceptualisation may, indeed, be applied to innovation-related factors steering the current system in the direction of another, more sustainable one. Notwithstanding their complementary nature, and the obvious fact that they are not always easy to separate in practice, the hard-soft dichotomy was applied to the CE transition.

Table 9 applies this view as a "focusing device" for organising the relevant literature at the CE-EI intersection. It distinguishes between "harder" factors, more

[19] It lacks information, however, regarding the methodological choices in the identification of that literature.
[20] Also unclear are the motivations regarding the choice of two particular cases from a pool of 52 collected by the EU-funded project *The GreenEcoNet*.

closely related to socio-techno-economic trajectories, and “softer” ones, having to do with regulatory and cultural issues.

	Drivers	Barriers
Technical and economic factors	***Hard drivers***	***Hard barriers***
Institutional and social factors	***Soft drivers***	***Soft barriers***

Table 9 - Factors facilitating and constraining the transition towards a CE

Based on existing literature, several broad factors driving and preventing the CE were identified in the corpus, in an iterative process, ranging from arguably the “hardest” (technical, economic) to the “softest” (social, institutional) factors (Table 10). The “drivers” are therefore factors that enable and encourage the transition to a CE, while the “barriers” are technical/financial impediments or regulatory/cultural bottlenecks that obstruct transitions towards a CE (Table 10). Typically, there is not just one important driver or barrier, but rather a mixture of facilitating and constraining factors, deriving from particular local conditions. The categories, therefore, should not be understood as mutually exclusive.

		Drivers	**Barriers**
“Harder” factors	**Technical**	availability of technologies that facilitate resource optimisation, re-manufacturing and re-generation of by-products as input to other processes, development of sharing solutions with superior consumer experience and convenience	inappropriate technology, lag between design and diffusion, lack of technical support and training
	Economic/ Financial/ Market	related to demand-side trends (rising resource demand and consequent pressures resource depletion) and supply-side trends (resource cost increases and volatility, leading to incentives toward solutions for cost reduction and stability)	large capital requirements, significant transaction costs, high initial costs, asymmetric information, uncertain return and profit
“Softer” factors	**Institutional/ Regulatory**	associated with increasing environmental legislation, environmental standards and waste management directives	misaligned incentives, lacking of a conducive legal system, deficient institutional framework
	Social/ Cultural	connected to social awareness, environmental literacy and shifting consumer preferences (e.g. from ownership of assets to services models)	rigidity of consumer behaviour and businesses routines

Table 10 - Typology and definition of drivers of, and barriers to, a CE

From an analytical point of view, such a framework allows for an appreciation of both the dynamics and the inertia of the CE. From a policy point of view, the framework may be of service to tackle policy-managerial dilemmas. Thus, this analytical and strategic tool clarifies the conceptual issues involved, while addressing the need to re-discover the non-technological meanings of innovation (see Hobson and Lynch, 2016; and Wildschut, 2017) laying ground towards new, imaginative, working paths ahead (Granjou et al., 2017; see Lowy and Hood, 2004).

4.2. Adding the grey literature to the literature revision – Methodological considerations

This section is focused on methodological considerations regarding the inclusion of grey literature to the previously analysed academic WoS and Scopus corpus (addressed in Chapter 3). This addition sought to minimise biases that would be present if only a single data source was in place. Both academic literature and policy reports were used so as to make the study more complete, balanced, robust and meaningful.

4.2.1. Grey corpus: The structure of the sample

As organisational and industrial practice can, in some cases, be ahead of academia in exploring new concepts, it seems prudent to put the academic corpus into perspective with the help of a different source. The tactic here is to use "grey literature", i.e. technical contributions not published as papers validated by normal scholarly procedures, but still professional and research-based. This includes reports and policy papers made by government organisations, "think tank" institutions and private companies (Schöpfel, 2010). Such grey works act, firstly, as a type of "control sample" for the academic literature. Secondly, they are also useful as examples of engaged discourse, oriented towards translating academic ideas into policy approaches and agendas.

The grey literature consists of over 40 works (detailed references in Appendix 2) published between 2006 and 2015[21] that generally discuss the CE and/or EI concepts.

[21] To facilitate the search (conducted online) the target period, ranging from 2006 to 2015, was chosen as this decade had been previously identified in the academic literature as the most prolific regarding these topics.

The reports come from prominent actors, such as the United Nations Environment Programme (UNEP), the United Nations Department of Economic and Social Affairs (UNDESA), the World Economic Forum (WEF), the European Commission (EC), the Eco-Innovation Observatory (EIO), the Organisation for Economic Co-operation and Development (OECD), the Ellen MacArthur Foundation (EMF), and several other institutions and enterprises.

The identification criteria of the grey sample included reports mentioned in the academic literature (chapter 3 - which, for example, identified quite a few EU-related publications). From these initial sources, other reports were then identified through a "snowball" method, using the references in the previously identified publications. This was followed by a wide search on the internet for publications in two languages (English and French), after which another snowball procedure was carried out. The final corpus of grey publications included reports, website published texts and press releases, totalling 43 publications, from 21 different organisations. The number of publications increased substantially in the 2010s, whilst those addressing both EI and the CE also increased during this period (Figure 9).

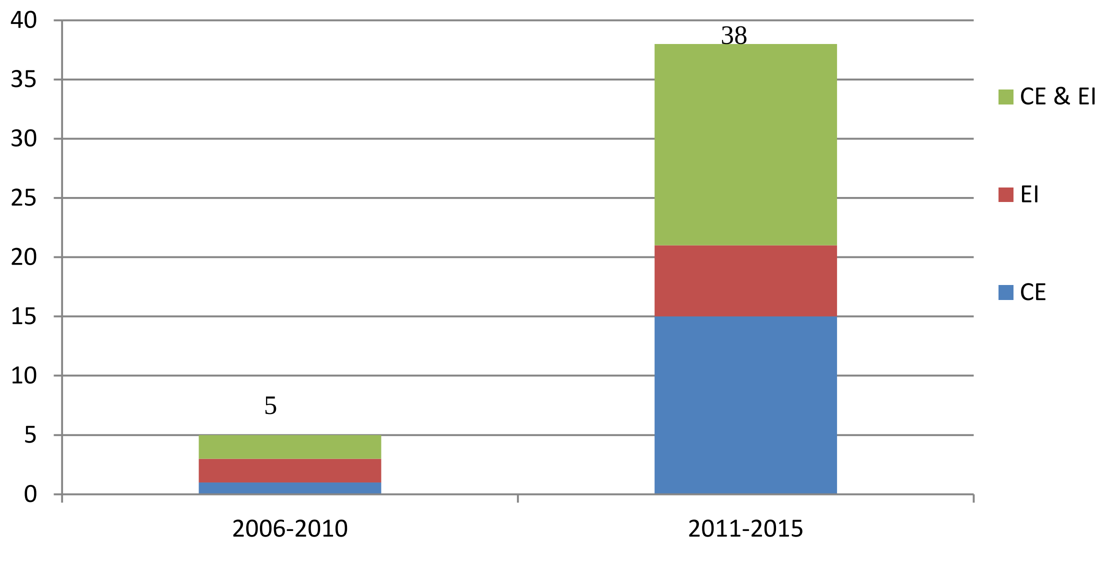

Figure 9 - Growth of grey literature mentioning the CE, EI and both concepts together, in the periods between 2006-2010 and 2011-2016.
Note: N=43. Elaborations on the grey corpus.

Almost all the publications mention innovation, as well as innovation's role in overcoming economic and social problems. Nevertheless, an explicit environmental concern is not always apparent.[22] The publications that address both the CE and EI comprise 44% of the sample, but are clustered in the years 2014 and 2015. The publications addressing both concepts scarcely quote academic sources, and instead cite previous EU reports or communications, and, especially, Ellen MacArthur Foundation reports.[23]

4.2.2. What is being studied by academia and institutional actors: Comparisons and contrasts

As expected, both types of literature have complementarities (summary in Table 11). The extraction of information from multiple types of documents and sources, resulting from different perspectives and agendas, was sought as to ensure a methodologically robust study.

	Academic literature	**Grey literature**
Time span	1992-2015	2006-2015
Focus	▪ Engineering solutions ▪ Environmental studies	▪ Economic benefits and costs ▪ Social sciences
Geography	▪ Cases identified around the world	▪ More focused in developed countries cases
Target audiences	▪ Academic ▪ Governmental agents	▪ Governmental agencies ▪ Enterprises
Outcome	▪ Adding to the available knowledge-base on the CE ▪ Recommendations or guidelines for the public policies	▪ Promote enterprise achievements and case studies ▪ Recommendations or guidelines for the public policies

Table 11 - Complementarities between the two sources of literature on CE and EI

The geographical origin of the CE phenomenon examined in the two bodies of literature is also useful for building a picture of the global distribution of this approach's practical application. The country of origin of each relevant CE example[24] within the literature sources was recorded. Each article/report, from both the academic and grey literature, cited several CE examples from different countries, and a total of 33 nations

[22] Therefore, only when environmental or sustainability-concerned innovation was identified were the publications categorised as mentioning EI.

[23] Highlighting the autonomy of the "grey sample" there are only two cited papers from our academic corpus, Lombardi and Laybourn (2012) and Paquin and Howard-Grenville (2012) in the report to the EU by Vanner et al. (2014).

[24] When recorded as "relevant" it is considered that the example was actually described and not only mentioned, including the institution/enterprise developing it, as well as the location.

were covered across all the sources. Figure 10 shows the countries locations where examples of CE were identified (red for the academic examples, and blue for the grey literature examples). Each circle represents the country capital, and its relative size indicates the number of examples cited from that country. The rising role of China is prominent: its government appears actively involved in CE implementation; and the academic corpus includes several examples of Chinese CE activities, typically as a top-down political objective for economic development (Ghisellini et al., 2016). Europe, Japan, Canada, Australia and the US also show developments in CE, although with a different perspective in the definition of environmental policies.

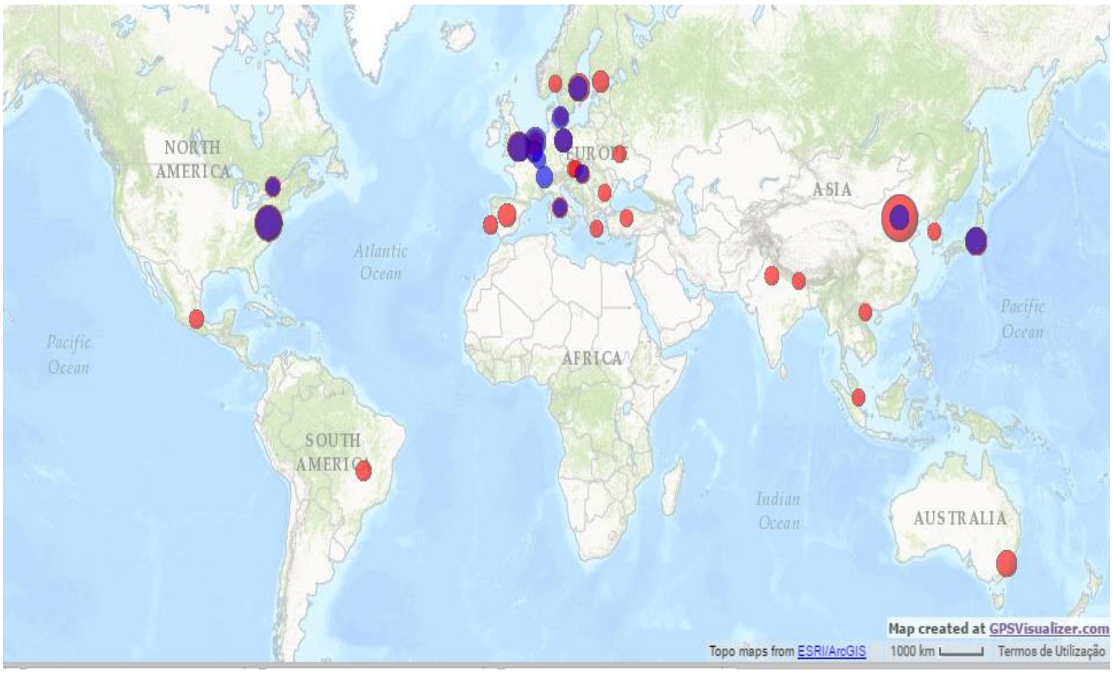

Figure 10 - Global distribution of CE examples mentioned in the academic (red) and institutional (blue) literature
Note: Elaborations on the academic and grey corpus. The number of times a country was mentioned, and the coordinates of its capital city, were entered into gpsvisualizer.com in order to generate the map. Each circle represents a country, focusing on the capital city. The relative size of the circle represents the number of times an example in that country was mentioned.

Re-aggregating the collected data, per continent,[25] it is possible to observe the differences between the two types of literature (Table 12). In the academic papers, Europe accounts for most examples, and this is even more the case in the grey literature, possibly indicating the existence of research funds, as well as the demand for solutions. The grey literature seems generally more focused on examples from economically

[25] Using the UN M49 composition of macro geographical (continental) regions (UN Statistics division, 2013).

developed countries, which contrasts with the academic literature, where some examples from emerging economies, such as Brazil, Mexico and India can be found. Examples from Africa are conspicuously absent.

Continents	Distribution of examples in the academic literature	Distribution of examples in the grey literature
Europe	45%	68%
Asia	30%	17%
Northern America	15%	16%
Oceania	6%	0%
Latin America and the Caribbean	4%	0%
Africa	0%	0%

Table 12 - CE global dispersion per continent
Note: Elaborations on the academic and grey corpus

4.3. Enabling and constraining factors in the Eco-innovation led transition to a Circular Economy

This section analyses the transition to a CE from the perspective of innovation and inertia. The analysis begins with the research papers, which are then complemented by inputs from the grey literature later on in each subsection. Some interesting patterns emerge. As Figure 11 suggests, taken together, softer CE drivers appear to be the factors most referred to in the academic literature. Institutional and regulatory drivers seem to be the single most present type of CE drivers among scholarly papers, which seems to point to the potential entrepreneurial role of policy in this field, as well as the role of corporate middle management. Figure 12 addresses the issues of barriers and shows that harder factors are paramount. Technical bottlenecks stand out as the perceived source of the greatest challenges. It is worth further examining these initial findings, as they reinforce the relevance of a systems view in this field.

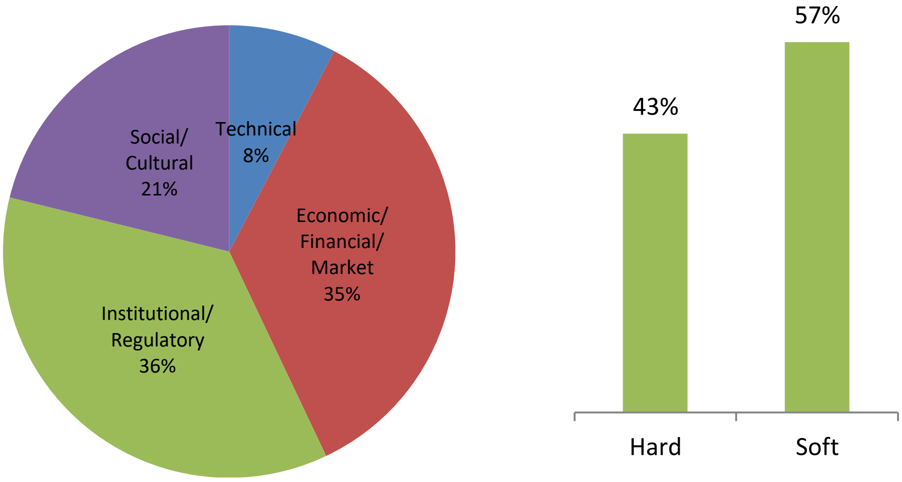

Figure 11 - Most mentioned CE drivers in the academic literature
Note: N=141

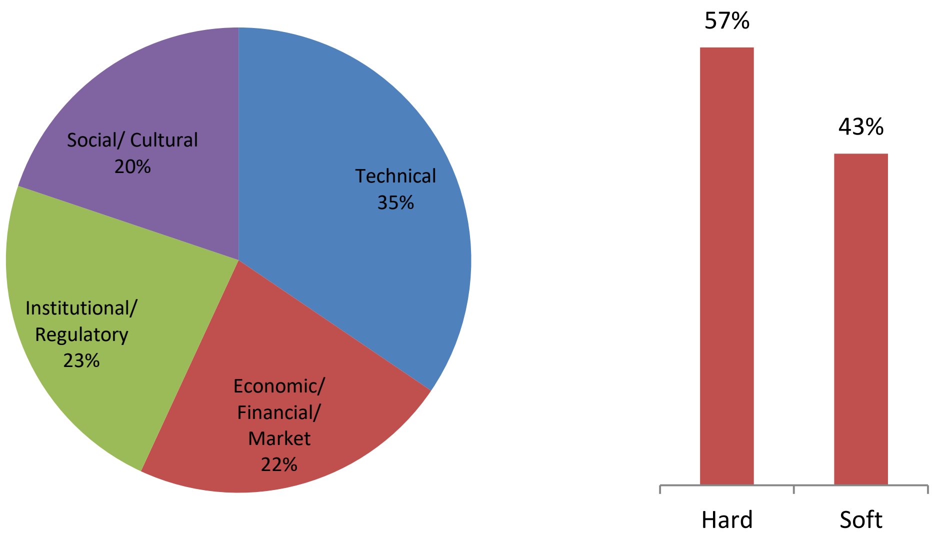

Figure 12 - Most mentioned CE barriers in the academic literature
Note: N=141

4.3.1. Hard drivers and barriers

4.3.1.1. Technical factors

Moving towards a new mode of sectoral organisation, and new business templates, inevitably has profound social and economic implications. However, it is also dependent on technical knowledge, as: "how we make things dictates not only how we work but what we buy, how we think, and the way we live." (Womack et al., 1990, p. 11) Changes are often perceived as triggered by the rise of new technologies: the steam engine impelled the industrial revolution; and, the development of computers, digital communication and microchips launched the 20th century information revolution (Johnson and Suskewicz, 2009). In the same way, technical capacities are now fundamental in the transition to a CE.

The availability of technical solutions is an essential condition for balancing product durability, efficiency, and quality, as well as for designing optimal product life-cycle scenarios for new products and processes (for example, products intended to be rented and restored numerous times require in-depth knowledge about ongoing enhancements and the optimisation of part replacement).[26] In product life extension "what determines the 'possibility' of reuse for a material is the extent of knowledge that has led to technological innovation for reuse. (…) The reuse potential increases as technological options increase, enabling more material recovery."[27] In recycling and waste management, the use of by-products as inputs for other processes/products is also dependent on technical capacities.[28] Likewise, the availability of information and communications technologies (ICTs) is considered a facilitator in the dematerialisation of the economy.[29] A CE seems, therefore, to be dependent on a broad array of technologies in order for it to gain widespread penetration.

As the availability of technical solutions is a condition for adaptability, and thus the development of a CE, technological challenges are considered to be a key barrier to transition (Figures 11 and 12). Technical barriers include not only factors concerning the existence of appropriate technology (technological thresholds),[30] but also technology gaps (such as the lag between processes and product development, and the lag between invention and production),[31] and the lack of sufficiently educated/specialised personnel.[32]

These barriers are not only stressed by the academic, but also by the grey, literature (EMF, 2015a, 2013, 2012; Vanner et al., 2014; WEF, 2014). The latter also adds warnings regarding the fact that "enormous technical hurdles need to be

[26] (Bakker et al., 2014; Mont, 2008). To enable an easier reading and to distinguish the literatures in this chapter, the academic corpus's references are gathered in footnotes.
[27] (Park and Chertow, 2014, p. 47).
[28] (Riding et al., 2015; Wen et al., 2007; Yu et al., 2015a).
[29] (Dewick et al., 2007).
[30] (Geng et al., 2014; Yu et al., 2014).
[31] (Gao et al., 2006; Kaenzig and Wüstenhagen, 2010; Pajunen et al., 2013; Vernay et al., 2013; Watkins et al., 2013).
[32] "lack of technical support and training" (Geng et al., 2010b, p. 1506).

surmounted to accelerate innovation and ensure widespread application of resource efficient and waste-reducing technologies, especially those related to energy." (UNDESA, 2011, p. 19)

Overall, and despite available technical solutions, even more technological innovation seems to be needed to enable a CE. Moreover, existing solutions are only very slowly entering the market, due to barriers linked to investment deterrents and market problems. It is not only S&T that need to be "re-wired": organisational and marketing assets also need holistic innovation.

4.3.1.2. Economic/Financial/Market factors

Even though, in some cases, technical solutions are already "out there", they often have limited practical application due to economic and market limitations (Figure 12). Obstacles, such as high initial costs and market uncertainty, limit new investments.[33] Moreover, prevailing socio-technical systems are often characterised by inertia and lock-ins, aggravated by strong path-dependencies that are difficult to overcome.[34] For instance, regarding eco-industrial parks in China, Zhu et al. (2015, p. 459) emphasise that "conflicts with financial gains, lack of a technical workforce, and lack of research funding are all barriers within China for promoting sustainable industrial development." New ways of overcoming financial barriers, arising from high upfront investment costs, emphasise the need for new financial tools, i.e. green financial innovation.[35] In addition, it should be noted that SMEs have particular difficulties in financing the innovation involved in the transition to a CE.[36]

Economic, financial, and market drivers are, nonetheless, important factors for powering the transition to a CE (Figure 11). As resource consumption, dependence, depletion and volatility continue to rise, the need to decouple revenues from material input, and to improve resource performance, is an important incentive that encourages enterprises and industries to generate new solutions.[37] Drivers stemming from the marketplace "can motivate manufacturers to initiate their sustainable purchasing

[33] (Matus et al., 2012; Reh, 2013; Sanyé-Mengual et al., 2014).
[34] (Markard et al., 2012).
[35] (Mathews and Tan, 2011).
[36] (Geng et al., 2010b).
[37] (Geng et al., 2014, 2010b).

efforts."[38] They can also change perceptions of the environment, from a source of costs, to something much more positive, ripe with business opportunities.[39]

The grey literature emphasises the importance of economic drivers. Current trends related to price volatility and increasing resource consumption[40] are stressed as promoters of new, more sustainable and circular, economic models (Preston, 2012). As for barriers, the grey literature underlines market failures, namely imperfect information, and investment costs (EMF, 2015a). Financial barriers, related to the cost of developing and implementing innovation, as well as the difficulty in overcoming linear economic lock-ins, are significant, constraining the adoption of new circular business models, especially in countries with financing difficulties and many small enterprises (Rizos et al., 2015).

4.3.2. Soft drivers and barriers

4.3.2.1. Institutional/Regulatory factors

In the academic corpus, "soft" institutional and regulatory drivers are extensively named as factors facilitating a CE (Figure 11). The emphasis is on public policy measures (e.g. legal frameworks, taxes, incentives, infrastructure development) addressing market failures, as well as the establishment of a conducive environment for innovation and entrepreneurship. Government is considered to play a leading role in promoting an institutional framework[41] "by reforming existing laws, enacting new regulations, promoting the application of new environmental technologies, and organising public education."[42] The importance of institutional/regulatory drivers in the implementation of a CE is analogous to the role of laws and taxes in boosting environmental-friendly technical change (Porter and Linde, 1995). That is, policy can have a double role: it modulates behaviour in a dynamic way, since its effects are not so

[38] (Zhu and Geng, 2013, p. 11).
[39] (Maurizio Catulli, 2012; Sanyé-Mengual et al., 2014).
[40] These amounted to around 65 billion tonnes of raw materials in 2010 with estimations pointing to 82 billion tonnes by 2020 (EMF, 2012).
[41] (Andrews and deVault, 2009; Bergquist et al., 2013; Carrillo-Hermosilla et al., 2010; del Río et al., 2010; Eckelman and Chertow, 2009; EMF, 2015b, 2012; Gao et al., 2006; Geng et al., 2012; Heyes and Kapur, 2011; Huesemann and Huesemann, 2007; Köhler et al., 2011; Levänen, 2015; Maurizio Catulli, 2012; Naveh, 1998; Nguyen and Ye, 2015; Pajunen et al., 2013; Subhadra, 2011; Tong and Yan, 2013; Vivanco et al., 2014; Watkins et al., 2013, 2013).
[42] (Geng et al., 2009b, p. 233).

much direct as they are indirect, i.e. by triggering reactions that are desirable by themselves.

In spite of its role as a driver of change, institutional/regulatory barriers are also one of the most important factors limiting the development of a CE. An "optimal" mix of taxes, rules, infrastructures and educational set-ups promotes the CE. On the contrary, non-conducive legal systems and misaligned incentives are not only hurdles, but also contribute to making the incumbent paradigm more entrenched. Environmental policies that influence the definition of what is, and not, waste, are an example of this, i.e. materials are often categorised as waste too quickly even if they, or some of their components, could still be reused, thus possibly hampering the development of industrial eco-parks and symbiotic relations.[43] Another example of conflicting policies is the promotion of product efficiency and, at the same time, stimuli for the replacement of old appliances, which sometimes carries the risk of overshooting, i.e. over-investment in new infrastructure that utilises more resources in its construction than it will ever save over its lifetime.[44] For instance, after years promoting incineration and infrastructure investment, the EU shifted towards a recycling strategy defining recycling targets and limitations regarding incineration. This U-turn amounts to a double investment in a short time span (Domenech and Bahn-Walkowiak, 2018). The enforcement of environmental regulations is another issue, as it is considerably more difficult to enforce than to promote laws.[45]

Adequate promotion and support of R&D, education and training, so as to increase general awareness and create the required skill base, is another necessary condition of the CE. In China, for example, public education on sustainable development is considered to be insufficient, resulting in too little public involvement in environmental protection.[46] Similarly, the contents of the CE are still poorly covered in university *curricula*, and training courses for improving industry's capacity in this area are rare.[47] Addressing this issue thus can also help to reduce barriers related to technical feasibility.

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[43] (Zhang et al., 2010).
[44] (Mont, 2008).
[45] (Geng et al., 2010b).
[46] (Gao et al., 2006).
[47] (Geng et al., 2010b).

The role of policies and regulations in the establishment of a CE is also emphasised in the grey literature. As the CE discourse entered political and business agendas, an institutional and legislative framing of such initiatives emerged (Vanner et al., 2014). The political discourse stresses that a CE "requires dedicated public policies and new forms of cooperation between enterprises and public actors."[48] (IAU, 2013, p. 16) In this respect, governments' role, in establishing a welcoming environment for EI and entrepreneurship (for example, regarding financial instruments), as well as in providing a solid education system (thus promoting more social participation in these issues, as well as improving stakeholder confidence and long term viability), is emphasised (EMF, 2015b, 2012). For example, and illustrating the perception of the importance of a regulatory and institutional framing of a CE, the EU 2015 Action plan "(….) establishes a concrete and ambitious programme of action, with measures covering the whole cycle: from production and consumption to waste management and the market for secondary raw materials", covering not only legislative efforts but also funding tools (EC, 2015a, p. 2).

4.3.2.2. Social/Cultural factors

Finally, trends such as social sensitivity to environmental problems, shifting customer preferences (from ownership to services models), and business perception of reputational gains, are considered social drivers of a CE (Figure 11). Demand-side factors are decisive in generating momentum toward greener practices, and more sustainable choices.[49]

Customers' desire for, and cultural acceptance of, circular business models, including "product service systems", "performance-based contracting", "product as a service", and "servitization" (i.e. provision of a service rather than ownership), is seen as only increasing slowly, resulting in slow diffusion of CE models (Evans et al., 2007). Consumer habits and businesses routines are only changing very slowly because of inadequate awareness and information regarding the CE concept and the possible choices available. This inertia is an important barrier.

[48] In the original "suppose également des politiques publiques dédiées et de nouvelles formes de coopération, entre entreprises et acteurs publics."
[49] (Andrews and deVault, 2009; Geng et al., 2010b; Maurizio Catulli, 2012).

In the grey literature corpus, inadequate investment in the education of consumers about circular business models is emphasised as a key gap. To address this issue, the EU refers to the need for new "ways of supporting co-creation by developing, experimenting and demonstrating new business models together with end-users, taking into consideration their needs" (EC, 2015b, p. 75).

4.4. Systemic Eco-innovation for a Circular Economy: An integrated assessment

In order to map the main arguments identified, sections of the original texts were used as explanatory illustrations of the key characteristics of the two types of literature (summarised in Table 13). Overall, the CE is characterised by a "reframing" of the sustainability discussion agenda and action, focused on economic viability and appealing to governments and the private sector, through the offering of general economic benefits and business-specific solutions. Boosted by global trends related to resource volatility and ever more stringent regulatory frameworks, the CE appears nevertheless hampered by technical and institutional factors. A broad transformation is seen as contingent on more than just S&T; i.e. a transformative change is based on a systemic approach to CE-friendly EI.

On the whole, the academic literature still seems focused on the role of technological innovation in the transition towards a CE. EI is understood as essential in overcoming "hard" technical aspects from solid wastes issues, to air pollution, water contamination and noise.[50] For example, technological developments in chemistry may involve the development of non-toxic or biological materials capable of substituting oil-based plastic packaging.[51] Other technological developments underscored include the capturing of waste, and the reintroduction of by-products as resources in the supply chain, thus reducing material inputs and environmental impacts.[52]

[50] (Geng et al., 2014, 2010b).
[51] (Grundmann et al., 2013; Matus et al., 2012; Reh, 2013; Wen et al., 2007).
[52] (Chen et al., 2012; Dong et al., 2013b, 2007; Ness, 2008).

Main arguments identified	Illustration from the academic literature	Illustration from the grey literature perspective
CE as a multidimensional concept	"circular economy does not have a single definition, it generally stresses closed flows of materials, and increased efficiency in the use of raw materials and energy." (Matus et al., 2012, p. 194)	"the specific origins of the circular economy is a highly complex, if not impossible, task as the concept has its roots in several different schools of thought and theories that question the prevailing linear economic systems"(Rizos et al., 2015, p. 1). " many are moving towards an industrial model that decouples revenues from material input: the circular economy." (WEF, 2014, p. 14) "it is based on the principles of natural ecosystems that operate in a closed loop, minimizing energy and materials loss." (IAU, 2013, p. 13)[53]
EI as a transitional pathway	"what determines the 'possibility' of reuse for a material is the extent of knowledge that has led to technological innovation for reuse." (Park and Chertow, 2014, p. 47) "capacity of eco-innovations to provide new business opportunities and contribute to a transformation towards a sustainable society." (Carrillo-Hermosilla et al., 2010, p. 102)	"Systemic eco-innovation is at the heart of this paradigm shift." (EC, 2015c, p. 4) "It aims to move societies from the extract, consume, and dispose system of today's resource use towards a more circular system of material use and re-use with less total material requirements overall." (EIO, 2012, p. 20)
Transformation is contingent on a transformative process based on systemic EI (i.e., more than just S&T is needed for transition)	"viewing infrastructure as an integrated system to deliver services ('infrastructure service systems'), applying systems thinking and extending the concept of product service systems, opens up many opportunities for integration and innovation, leading to much increased resource or eco-efficiency." (Ness, 2008, p. 299) "While technological solutions form an important part of this progress, a resource efficient circular economy requires more than technological solutions alone." (Corder et al., 2015, p. 3) "Innovative firms can create green products in response to or in anticipation of government regulation, but true green niche markets do not emerge unless there are also green consumers." (Andrews and deVault, 2009, p. 326)	" the success of circular economy models will depend on adopting a systemic approach to eco-innovation that encompasses value and supply chains in their entirety and engages all actors involved in such chains." (EC, 2015b, p. 73) "research and innovation are key for the EU to achieve a systemic approach to eco-innovation for a circular economy." (EC, 2015c, p. 4) "Systemic eco-innovation requires more than science and technology. It requires new alliances, often with the engagement and the involvement of citizens, communities and municipalities building on a general environment that welcomes and is excited by innovation." (EC, 2014d, p. 19)
Government's role is one of the essential drivers	"appropriate conditions and measures should be arranged by governments to prompt the diffusion of new sustainable goods and technologies, starting from the beginning of the transition phase." (Barbiroli, 2011, p. 25) "governmental agencies should play a leading role by coordinating different initiatives, enacting appropriate regulations " (Geng et al., 2010b, p. 1507). "Fiscal and regulatory policies have an impact in shaping the structure and processes of industrial ecosystems." (Pizzocaro, 1998, p. 231)	"Stimulating the circular economy requires extensive policy support"(EC, 2014c, p. 3).
But established legislation is also an important barrier	"In achieving a recycling society there is the need to continuously improve regulatory procedures so that they do not act as impediments to successful and environmentally acceptable residue utilisation." (Pajunen et al., 2013, p. 154). "Regulation could be perceived as the more challenging barrier to overcome" (Riding et al., 2015, p. 63). "Regulatory and bureaucratic issues are still key obstacles" (Zhu et al., 2015, p. 457).	"The barrier of unintended consequences from existing legislation limiting circular economy opportunities is present for example in bio-refining where food safety regulations prevent the use of certain animal products as feedstock." (EMF, 2015b, p. 102)

Table 13 - Main arguments identified in the academic and grey literatures

[53] In the original: "*s'inspire des principes de fonctionnement des écosystèmes naturels qui fonctionnent en boucle fermée, en minimisant les pertes d'énergie et de matières*".

EI is also considered to be key for expanding the available knowledge base and promoting cooperation between actors.[54] The large number of eco-industrial parks, where industrial symbiosis has been developed, underlines just how crucial EI has proven to be for creating new ways of sharing services and re-utilising by-products among diverse industrial processes or actors.[55] Even concerning financial barriers, transformational innovations are seen as instrumental for overcoming economic barriers, given large capital requirements and high initial costs.[56] Financial innovation remains, nevertheless, a rather neglected area in innovation studies (Martin, 2016).

As for addressing "soft" barriers, institutional and social innovations, encompassing the efforts of several actors (government, organisation and industries), are considered essential in a CE.[57] Nevertheless, the promotion of new business models and consumer awareness of the benefits of a CE is still perceived as lacking.[58] This may be related to the fact that innovation studies have often been near-sighted regarding new forms of innovation, favouring an analysis of the incumbent and most visible actors (e.g. manufacturing, high-tech, big firms, etc.) while somewhat overlooking citizens, consumers and civil society influences (Stirling, 2011). A hybrid approach to innovation, considering it to be not only led by large enterprises and public-private partnerships, but also by "grassroots" innovation movements, more centred in civil society, is scarcely addressed in science-push, top-down policy and multilateral events such as the Rio+20 (Ely et al., 2013).

As for the grey literature, in addition to underlining the importance of technological innovation, it also emphasises the need for more comprehensive innovation schemes "from product design to new business and market models, from new ways of turning waste into a resource to new modes of consumer behaviour" (EC, 2014d, p. 2). This literature stresses an EI approach towards the development of a CE sensitive to the "interaction between actors in the system (businesses, governments, knowledge institutes, social groups), institutions (rule, laws, routines) and technologies" (Bastein et al., 2013, p. 93). A more complete view of innovation, which can be labelled

[54] (Yu et al., 2014).
[55] (Chertow and Ehrenfeld, 2012; Liu et al., 2012; Mathews and Tan, 2011; Shi et al., 2010; Shi and Yu, 2014; Yu et al., 2014).
[56] (Mathews and Tan, 2011).
[57] (Cerceau et al., 2014; Chen et al., 2012, 2011; Davelaar and Nijkamp, 1992; Dong et al., 2014, 2013a, 2007; Geng et al., 2010a; Langen, 2005; Liu et al., 2014; Ness, 2008; Niza et al., 2009; Patala et al., 2014; Ruiz Puente et al., 2015; van Berkel et al., 2009).
[58] (Albu, 2011).

as “systemic”, would leverage both streams of analysis, and suggest innovation trajectories rooted in inter-related developments and sectors (see Fagerberg et al., 2004). The drivers of sustainability-inducing change are many and, although this dynamic is not explicitly explored in the present chapter, their interaction is non-trivial (Cecere and Martinelli, 2017). One implication is that, as Constantini et al. (2017) show, portfolio approaches to policy that take into account spillover effects from the outset, tend to generate more effective outcomes.

Particularly in EU reports, the importance of a “systemic” EI approach towards a CE is already clear. The CE transition is considered contingent “on adopting a systemic approach to eco-innovation that encompasses value and supply chains in their entirety and engages all actors involved in such chains” (EC, 2015b, p. 73). The EU has, in fact, been one of the most active players in the development of a CE, directing its environmental agenda to include more circular considerations. The EU’s CE agenda is nowadays part of wider efforts to make the European economy more sustainable while, at the same time, boosting the EU's competitiveness, creating business opportunities, jobs and opportunities for social integration and cohesion. The 2015 EU Circular Economy Action Plan stresses the EU's commitment, whilst also recognising the linkages between implementing the CE and EI (Domenech and Bahn-Walkowiak, 2018; EC, 2015a). In the most recent EU report, concerning progress on key initiatives of the 2015 Action Plan (EC, 2017b, 2017a), the (systemic) impact of European Commission strategy can already be seen, not only at the EU level but also at the country level. Table 14 shows an implementation of the framework using this literature.

The analytical challenge, however, is to grasp and direct “innovation systems” towards not only corporate but also social “circular” practices. This would be tantamount to what Schot and Steinmuller (2016) refer to as “transformative innovation”. The “transformation turn” in innovation studies may yield a working frame to make sense of the recent discussions on the regulation of risky technologies (Bonnín Roca et al., 2017), the governance of access to emergent knowledge (Gans et al., 2017), the enhancement of inducements for up-stream innovation (stimulating the local generation of local inputs, e.g. Chakraborty and Chatterjee, 2017) and the facilitation of competitive diffusion of critical green downstream solutions (such as storage technologies, see Fabrizio et al., 2017; and Stephan et al., 2017).

	EU	Portugal
Technical	"calls have also been launched in 2016, within the framework of the Public Private Partnerships on "Factories of the Future", "Sustainable Process Industries" and "Bio-based Industries" to help develop and deploy the necessary key enabling technologies to support EU manufacturing across a broad range of sectors." (EC, 2017a, p. 12)	"several initiatives were launched in 2015 specifically targeting resource efficiency through eco-innovation in industry, serving as "living labs" to pilot technologies, sharing of best practices and providing a platform to raise awareness on circular economy and the future of the industry." (EC, 2017b, p. 7)
Economic	"January 2017 (…) a platform is launched, bringing together the Commission, the European Investment Bank (EIB), financial market participants and businesses to increase awareness of the circular economy business logic and improve the uptake of circular economy projects by investors." (EC, 2017a, p. 7) "The Horizon 2020 Work Programme 2016-17 invests € 650 million in a Focus Area on "Industry 2020 in the circular economy" which grants funds to demonstrate the economic and environmental feasibility of the circular economy approach" (EC, 2017a, p. 12).	"The support of the EU funding has significantly contributed to improve the implementation of the EU environmental law and policy and Portugal. (…) [The "Sustainability and Efficiency in the Use of Resources" (POSEUR)] aims to anticipate and adapt to the global changes in the field of energy, climate change and more efficient use of resources" (EC, 2017b, p. 25).
Institutional	"The actions delivered by the Commission since the adoption of the Circular Economy Action Plan include several legislative proposals (…) establishing an ambitious long-term path leading towards waste prevention and recycling" (EC, 2017a, p. 3).	"From 2013 to 2015 several national plans were revised (waste, water), placing strong emphasis on efficiency and meeting EU targets in the most cost-effective way, and new types of policies were introduced (e.g. Green Taxation Reform). It can be specially highlighted the Green Growth Commitment, a national strategy adopted with the purpose of reorienting the country's economic development which is now focusing on the circular economy." (EC, 2017b, p. 6)
Social	"the Commission adopted a revised version of its guidance on the Unfair Commercial Practices Directive (…) which includes specific elements to make green claims more trustworthy and transparent. (…) Misleading claims can result in consumers losing confidence in labels and in companies being discouraged from making truthful and relevant claims, altogether hampering the circular economy." (EC, 2017a, p. 9)	"In 2016, the Ministry of the Environment has created a working group to further develop the green taxation reform approved in 2014. This work should aim to deliver more incentives to green behaviour" (EC, 2017b, p. 24).

Table 14 - European Commission strategy as a driver for overcoming CE barriers - The Portuguese example as an application

As for the corporate world, although "in the driver's seat in the transition to a circular economy" (EC, 2014c, p. 2), it nevertheless seems to be slow in adjusting its own business models and environmental considerations. Examples, such as Coca-Cola using renewable, plant-based materials in packaging (Coca-Cola, 2015) or

Nestle/Nespresso's collecting and recycling used Nespresso capsules (EMF, 2012, 2014a, 2015a) are still exceptions. Also, both academic and grey literatures are consistent regarding warnings as to the ambiguous value of circular business models and EI's environmental credentials. Critical considerations regarding the "goodness" of innovation must guide the integral analysis of the process of transition. Innovation is not enough. Systemic, transformative, and effectively sustainable, innovation is a pre-requisite for sustainability, as some pioneering examples around the world are already demonstrating (Box 1).

Box 1 - EI pathway toward CE implementation: Samsø, an example of systemic EI CE

Transition is more than focusing on unique pathways, or "silver bullets". Relevant cases such as pilot projects and demonstration markets can be interpreted as fundamental sign posts of new values and modes of organising that do not depend on single factors but rather on complex societal processes engaging many actors and sectors in holistic ways (Huguenin and Jeannerat, 2017).

The Danish island of Samsø stands as a pioneer example of a successful "green community". Samsø was, till the end of the 20th century, entirely dependent of imported oil and coal (Brandt and Svendsen, 2016). In 1997 the island won a competition to be a "Renewable Energy Island" (REI). A 10-year plan followed to develop a self-sufficient energy supply base, running on renewable energy. By 2005 wind, solar and biomass fulfilled that goal (Jørgensen and Nielsen, 2015; Nielsen and Jørgensen, 2015). More recently (October 2015) Samsø launched the "Full Circle Island" project, an initiative intended to make the island the first "circular" community.

What are, therefore, the conditions that allowed those accomplishments? The success of the REI project and the island's aspirations regarding circularity has been credited to the convergence of a set of factors of different nature. The key was the systemic integration, and mutual reinforcement, of many elements.

Initially, the transition process relied on hard factors (our terminology; see Sperling, 2017). It was facilitated by *technological drivers* (wind turbines, district heating plants and solar thermal plants). National funding of costly infrastructures was a fundamental *economic driver* as well, accompanied by a variety of incentive schemes for renewable energy adoption, which succeeded in nudging household choices.

But *soft* factors also contributed to support the process (see Brandt and Svendsen, 2016). On the one hand, visions articulated at the national level were an *institutional driver*, providing clear guidelines and coherence to the project. On the other hand, local popular involvement, effective communication and a vibrant cultural context emerged as *social drivers* too (Kaltenborn et al., 2017).

4.5.Main Conclusions

Which factors are helping, and which factors are hindering the CE? Within the sustainability transition debate, and using an innovation studies perspective, this chapter attempts to provide some insight regarding soft and hard factors, as well as the broader role of EI in the transition to CE. In order to provide checks and balances in the analysis, two types of literature sources were contrasted: academic (WoS and Scopus papers) and grey (reports and policy papers). The systematic review of the academic literature enabled a scientific identification of some facts, as well as the assessment of the most important CE barriers and drivers. The grey literature provided a form of "sensitivity analysis", an alternative type of content that was used to appraise the information gathered through the academic review.

Globally, the CE was found to be driven particularly by "soft" (i.e. social, regulatory or institutional) factors. Public agencies have a crucial role in institutional framing, from infrastructures to legal set-ups, as well as in R&D support and increasing social awareness. At the same time "hard" barriers, related to the availability of technical solutions and financial factors, can hamper expansion of the CE. Even when CE solutions are already technically feasible, their practical implementation is often limited by economic and market limitations. EI is considered to be an essential pathway for overcoming barriers to a CE transition. Although academic literature still focuses mostly on technologically-based innovation, grey literature sources (and in particular EU reports) increasingly refer to systemic innovation.

Underlining the heterogeneity of the issue, a key conclusion is that the innovation system's view should not be lost when considering the transition towards a CE. A multidimensional, multi-actor CE is argued for, requiring not only technological innovation but also broad institutional change in markets, public policies and social practices. As Schot and Kanger (2016, p. 25) state: reinventing "the way we innovate" is the key for this transition. In innovation studies of transition this novel "transformation turn" perspective paves the way to a more dynamic conceptual, empirical and policy approach to CE. This chapter argues EI is a centre-piece of this emerging research program.

Regarding policy implications, institutional framing is in itself a driver, but it also carries risks for a CE. A coherent strategic roadmap is therefore essential for avoiding mismatches and contradictory incentives. The focus on the promotion of systemic EI is also of paramount importance. The challenge is, nonetheless, to direct "innovation systems" towards CE-inducing productive and social practices.

The unavoidable methodological and database limitations of this chapter point to avenues for further research. First, whereas this chapter adopted an interpretation-rich and hands-on approach to bibliographic data, other techniques (such as text mining) may be able to take this research further. Second, the CE framework requires more empirical content, so as to bring forward evidence of its actual "transformational" value (Schot and Kanger, 2016). Third, more information is required regarding heterogeneity in implementation of the CE, so as to address interactions and linkages, as well as trade-offs and mismatches, between technological and socio-institutional systems (Stirling, 2011, p. 83). Finally, a deeper understanding is needed regarding the specific EI tools required for achieving a ("transformative" and "systemic") CE "transition". In this sense, the insights that are wired up in this chapter aim to help facilitate the development of policy guidelines and organisational strategies. Moreover, a deeper understanding of the connections between the CE and EI is still elusive, requiring more empirical methods for assessing and measuring their mutual influence, in particular regarding the role of EI in implementing a CE.

PART II – INNOVATION TO A DYNAMIC CIRCULAR ECONOMY - ASSESSING CHANGE

Just as the concept of circular economy (CE) arrives to the policy arena, concrete action and guidelines on how to unlock the conditions for redirecting current socio-economic pathway into a more circular model are on demand (Dahl, 2012). As a CE is argued as requiring multidimensional, multi-actor, technological innovation, but also comprehensive institutional change in policies, markets and social practices, redirecting innovation systems towards a more "circular" paradigm should improve CE dissemination and a broader implementation. As Lundvall (2007, p. 115) argued "directing the efforts of the innovation system toward solving crises in ecological and social terms may be necessary in order to avoid real 'limits to growth'".

Nevertheless, a comprehensive discussion concerning CE empirical indicators is still in the early stages (Elia et al., 2017) while the literature addressing eco-innovation (EI) governance and policy does not seem to reflect on innovation convergence to circularity (Hillman et al., 2011; Lieder and Rashid, 2016). In that consideration the second part of this work aims to present and test an empirical approach to serve as a diagnosis tool of EI "circularity", particularly focusing on innovation systems. Innovative performance is influenced by actors and their interactions as system components (Hillman et al., 2011). Therefore, understanding innovation systems dynamics, with a particular focus on their "circular" activities may, first, allow an assessment of CE implementation and, secondly, enable the definition of policy implications and a more coherent CE roadmap.

Acknowledging the importance of indicators as a policy instrument in governance (Hezri and Dovers, 2006), and as available indicators fall short in assessing EI circular development, an "EI circularity assessment compass" was proposed (Chapter 5) using known technological proxies (patents – Chapter 6) and capitalizing on underexploited non-technological variables (trademarks – Chapter 7) that are still to be applied to the CE. The approach was developed in the context of Portugal, a moderately innovative economy, which may reveal features simultaneously interesting for more advanced, as well as catching-up countries. The aim was to identify an empirical focusing device to ascertain an innovation system's proclivity to a CE.

CHAPTER 5

INDICATORS OF WHAT, INDICATORS FOR WHAT: PROXIES OF TRANSFORMATIONAL SOCIO-TECHNO-ECONOMIC CHANGE

Nowadays, science and innovation "goodness" have been challenged (Fagerberg et al., 2015). Not all innovations are socially sound, or ecologically progressive, as they may entail negative consequences when appraised more globally (Soete, 2013). Innovation *per se*, is not enough in addressing policy puzzles as adverse as climate shifts, devastating pandemics, demographic unbalances, exploding urbanisation and other transnational phenomena provoking stress in existing social, economic and political structures (Foray et al., 2012). Above else, these problems have not declined, but worsened, accentuating the necessity of a new regime of renewed innovation policy and, consequently, the need to empirically understand how individuals and collective agents mobilise and succeed in meeting those "grand challenges" (Schot and Steinmueller, 2016). Nevertheless, even though innovation policy measures are now employed transversely in several policy areas, those are frequently underevaluated (Edler et al., 2016).

Indicators do not just quantify phenomena, as they do not simply reflect reality. Indicators enshrine analytical priorities thus framing mind-sets and unavoidably shaping policy goals. In a word, indicators are performative (Freeman and Soete, 2009). After some time, policy metrics tend to be held as goals in themselves. And so, by being strategically targeted as reputational goods, indicators risk to diverge from the actual performance they are supposed to objectively record and track. The implication is clear enough: a continuous degree of "creative destruction" is needed in the datasets and toolboxes employed to map and measure the emergence of transformative change in the contemporary economy. Next section intends to discuss circular economy (CE) main empirical indicators and their limitations (section 5.1). Following this debate, the objective was to analyse whether and how eco-innovation (EI) proxies could be stretched to cover CE-inducing EI (section 5.2). Lastly, an empirical "focusing device" was proposed, in order to gather new insights on the understanding and evaluation of the progress of pro CE EI (section 5.3).

5.1.Circular Economy Indicators

If CE is an approach to transition, then necessarily it implies movement. Acknowledging its relevance in the policy sphere, several ways to show the emergence of circularity (or lack thereof) have been developed (EASAC, 2016). Organisations such as the United Nations, Eurostat, European Union, OECD, but also the World Bank, the Global Reporting Initiative, and the Ellen MacArthur Foundation have been engaged in this effort (Table 15).

Indicator	Focus	Organisation/ Source example
Sustainable Development Goals	Sustainable Development	United Nations Development Programme (UN General Assembly, 2015)
Indicator for material consumption	Resource efficiency	United Nations Environment Programme (UNEP, 2016)
EU Resource Efficiency scoreboard	Resource efficiency	EU /Eurostat (European Union, 2016)
Raw Materials Scoreboard	Raw materials	European Innovation Partnership (EIP) (EC, 2016b)
Little Green Data Book	Environment and sustainability	World Bank (World Bank, 2017)
Green Growth Indicators	Environment, resources, economic, policy	OECD(OECD, 2017)
Sustainability Reporting Guidelines	Environmental impact from the activities of the company and its supply chain	Global Reporting Initiative (GRI, 2015a, 2015b)
Circular economy indicators	Measuring how restorative the material flows of a product or company are	Ellen MacArthur foundation (EMF) (EMF and Granta Design, 2015)
LCA	Environmental impacts of products and services in a life-cycle perspective	(EC, 2014e; Silva et al., 2015; Yu et al., 2015b)
MFA	Quantify flows and stocks of materials or substances in a system	(Geng et al., 2012; Silva et al., 2015)
Emergy	Environmental indices	(Geng et al., 2014, 2013)

Table 15 - CE Indicators
Note: Inspired on EASAC (2016).

Nevertheless, work so far can be described as somewhat patchy with several approaches reframing previously existent indicators. A (non-exhaustive) list of recent efforts has necessarily to include attempts that do not start from a fully circular point of reference (Table 15). Among key examples are developments such as the material flow analysis (MFA[59]), life-cycle analysis (LCA[60]), eco-efficiency and ecological footprint (Birat, 2015; Dong et al., 2013b; Spaargaren, 2000; UNEP, 2011). These indicators are among the first that could be approximatively regarded as yardsticks of progress toward a CE.

Several strands of work under the UN can be considered connected to the CE approach. The UN Environment Programme promoted the use of indicators like the “material consumption indicator”, which focuses on material efficiency (UNEP, 2016). Likewise, the seventeen Sustainable Development Goals of the UN Development Programme include indicators related to resource use, climate action, responsible consumption and production. These are inherently linked with CE’s dimensions and, therefore, are also considered CE indicators (UN General Assembly, 2015). The OECD “green growth indicators” was another such venture; this initiative considered resource productivity, natural asset safety, the environmental dimension of quality of life, and economic opportunities related to green business (OECD, 2017).

Additional examples include Eurostat’s “Resource Efficiency Scoreboard” (European Union, 2016) or the European Innovation Partnership (EIP) “Raw Materials Scoreboard” (EC, 2016b). Other EU initiatives are still under-development, such as the “Platform on Life Cycle Assessment” and the “Raw Material Consumption indicator” (RMC) - an aggregate indicator measuring all the material resources used in the economy, including those incorporated in imports (EC, 2015a, 2014f, 2014d). With these efforts, the EU has been contributing to the development of more rigorous and reliable indicators of pro-CE changes.

In the business world, the Global Reporting Initiative and its "Sustainability Reporting Guidelines", covering companies’ indicators concerning materials, energy, water, waste and recycling, also includes several indicators that can be used in CE assessment (GRI, 2016).

[59] Method used to quantify flows and stocks of materials or substances in a system (Silva et al., 2015).
[60] Technique used to assess environmental impacts of products and services in a life-cycle perspective (Silva et al., 2015)

One other set of indicators have also been used in CE implementations, the emergy-oriented figures. The "*emergy indicator system"* derives from ecology, thermodynamics and systems theory. The goal is to arrive at a sum of all available energy directly or indirectly required by a process to generate results, including intensity and performance appraisals (Geng et al., 2014, 2013). In the CE context this type of assessment has been mostly used for the evaluation of "industrial symbiosis" and "eco-industrial parks" in China, with few applications in other geographies or contexts (see e.g. Wu et al., 2018).

None of the above sets of indicators were, nevertheless, originally designed to assess CE, as such they sometimes lack coherence and overlook some of CE's specificities. The perception of incompleteness and ad-hocness justify the development of new approaches. For instance, in 2012, the EMF developed a composite indicator, the "Material Circularity Indicator" (MCI). The MCI evaluates the inputs in the production process, their usefulness during the usage phase, the destination of leftover materials after use, and the efficiency of recycling (EMF and Granta Design, 2015). It is, nevertheless, an indicator targeting products at a company level, difficult to stretch to a national or regional level.

In spite of the several inroads in accessing CE, from which we discussed only the most commonly used (EASAC, 2016), "monitoring and assessing the performance of the circular economy is still a challenge due to insufficient presentation of the circular economy elements by existing indicators" (EIO, 2016, p. 201). In the one hand it is necessary to ensure that CE is monitored from a systems perspective, in order to prevent that incoherent, cherry picked, indicators be used to fit a specific agenda rather than measuring real CE development and wider sustainability goals (Pauliuk, 2018). On the other hand, the absence of specific CE indicators taking an explicit innovation angle seems a particularly relevant shortcoming. How then could innovation indicators be used to access CE at a systems level?

5.2.Indicators of (eco) innovation

Given the complexity and heterogeneity of innovation phenomena, several approaches and a wide array of metrics have been traditionally used to characterise the rate and direction of change in companies, sectors and countries. A standard dichotomy is usually established between input and output indicators (Patel and Pavitt, 1995). Aligned with the third version of the Oslo Manual (OECD, 2005), this is a vision influenced by manufacturing and high-tech definitions of innovation, but also including other types (such as service and marketing) of innovation. Since all indicators are bundles of imperfect compromises, it is worth taking stock of the work already done.

Regarding *input* indicators, R&D (spending, staff, etc.) allows the observation of knowledge-seeking activities in enterprises (mainly at the applied research level) and government (in terms of public funding and/or execution of basic science, particularly in universities and research institutes) (OECD, 2008; Patel and Pavitt, 1995). Both indicators are easily accessible and come in long-time series. In what sustainability is concerned, R&D expenditure (as a proportion of GDP) and researchers (per 1 million inhabitants) have been used to monitor countries performance in the Sustainable Development Goal 9: "Build resilient infrastructure, promote sustainable industrialisation and foster innovation" (UN, 2017). Other lines of work have been debating R&D investments as an indicator of technical change in the reduction of CO2 emissions (Fernández Fernández et al., 2017) and as a proxy to inform climate change policy (Baker et al., 2009). At a company level, R&D has also been used for assessing the relationship between environmental R&D and businesses financial performance (Lee et al., 2015; Lee and Min, 2015).

Nevertheless, these indicators have several limitations as they better capture overall technological activities, rather than estimate developments in specific sectors (that is to say, developments in some sectors are overlooked by these metrics, for instance in ICT or services). Also, technological development efforts of small enterprises are understated when looking only to these kinds of indicators. Likewise, investment in "R&D" says little about market acceptance (Lane, 2012). As a result, the use of these indicators is not sufficient, failing to capture real outreach.

Regarding *output* indicators, several have been abundantly used in innovation studies, the most influential being bibliometric data (publications that point formal knowledge results and their intellectual impact); and patent information (records of claims to ownership of significantly new and industrially useful technological ideas) (Hamdan-Livramento et al., 2016; Moed et al., 2004; Patel, 2006). Besides these indicators, other complementary proxies have been gaining importance like design data (especially in assessing goods/ services innovation) and trademark analysis (reveal potentially marketable technical advances) (Galindo-Rueda and Millot, 2015; Millot, 2009; OECD, 1992).

Among many other examples there are already several bibliometric analyses focusing on factors that stimulate different types of EI (Hojnik and Ruzzier, 2016) or on EI models (Xavier et al., 2017). In what patent indicators are concerned, these have been studying the development and diffusion of environmentally-friendly technologies (Hall and Helmers, 2013). Trademarks and design indicators, despite being seen as indicators of innovative activity (Gotsch and Hipp, 2014; Mendonça et al., 2004a; Millot, 2009) have scantly been used regarding eco-innovation.

Other empirical strategies that have tried to combine input and output indicators took the form of *scoreboards* (composite indicators) and surveys (usually very costly) (OECD, 2010a). The Eco-Innovation Scoreboard (Eco-IS) and the Eco-Innovation Index are examples of efforts to capture the different aspects of EI in EU Member States.[61] The key information of the component indicators of Scoreboards maintain known shortcomings whereas the final unidimensional index is often sensitive to weighting and not amenable to easy interpretation (Gian et al., 2015; Godinho, 2007).

An example of a broad scale survey is the EU Community Innovation Survey (CIS) focused on comparing structure and innovation patterns in European countries, including a set of questions dedicated to EI. Using that data, several studies have already addressed issues concerning, for instance, firms motivations for introducing EI (Veugelers, 2012) or EI determinants in several countries (Horbach, 2016). Nevertheless, the complexity of surveys such as the CIS implies that the statistics are usually published with a considerable lag after their completion. Surveys are also very expensive and time-consuming while response rates are typically low, compromising attaining a representative sample (Godinho, 2007; OECD, 2010a).

Even if so far not much light has been cast over whether or not these innovation indicators can be stretched to cover CE-inducing EI, they remain flexible empirical instruments and several possibilities could be adapted to assess EI's "circular characteristics", especially the *output* indicators, as highlighted in Table 16. Which among those were found to be the most interesting innovation proxies in CE assessment

[61] This Scoreboard includes 16 indicators grouped into five dimensions, namely: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes (EC, 2017c).

and in what analytic framework could they be analysed will be discussed in the following section.

Indicator		Description	Examples of application to EI	Possible application to CE
Harder – Technical and economic	**R&D statistics** (R&D spending, personnel, etc.)	Input indicator points to investment trends in S&T. It does not provide data about the direction, results and impacts of R&D. Underestimates the performance of SMEs, services, and innovative firms not having large industrial labs.	-Assessing the relationship between enterprises green research, carbon emissions and financial performance (Lee and Min, 2015). -R&D is considered not sufficient to analyse green technology innovation (Lane, 2012).	Limited application to CE as is difficult to identify CE-specific R&D. If innovative CE-specialised firms are identified this indicator may be useful.
	Patents	Output indicator of invention and technological progress. Detailed data on technical specifications. With limitations as to the propensity to patent across countries, sectors, firms, industries.	- Studying the diffusion of green technologies (Hall and Helmers, 2013) - Measuring innovation in environment-related technologies (Haščič and Migotto, 2015)	Underexploited indicator that has great potential as there are already several classification schemes related with "green" and "environmental technologies" available, containing detailed, historical and updated information, which can be used to ascertain of the "circularity" of the technology.
Softer – Institutional and social	**Trademarks and Collective Trademarks (Certification/ /Labels)**	Output indicator. Reveal potentially marketable non-technological advances. Can be used to gather information on goods and services and marketing innovation. Enables the gathering of data at the company level and comparison between enterprises (benchmarking) Limited information on market success.	-Application mainly in innovation studies (Gotsch and Hipp, 2014; Mendonça et al., 2004a) -Collective trademarks have been use to study green innovation strategies (Corrocher and Solito, 2015)	Underexploited complementary indicator specially in low-tech industries , goods/ services and marketing innovation Can be used to gather information closer to the market
	Design	Output Indicator. Focus on designing activities: technical specifications/user and functional characteristics. Potential complementary indicator in goods/ services innovation	-Application mainly in innovation studies (Galindo-Rueda and Millot, 2015; Moultrie and Livesey, 2014; Perks et al., 2005)	Underexploited complementary indicator specially in goods/ services innovation
Other indicators	**Bibliometric and Citation Analysis**	Output indicator used for examining knowledge growth. Easily accessible and abundant. Lacks information on practical significance.	- Identifying the factors that stimulate different types of EI (Hojnik and Ruzzier, (2016) - Reviewing EI models (Xavier et al., (2017)	There are already applications of this indicator regarding: - CE origins and basic principles (Ghisellini et al. (2016), - CE state of the art (Geissdoerfer et al., (2017).
	Surveys	Provides information on all innovative activities (wide coverage). It is nevertheless expensive, time-consuming, and response rates are typically low (may produce a non-representative sample)	-The EU Community Innovation Survey (CIS) includes a set of questions dedicated to EI (Godinho, 2007; OECD, 2010) Study of EI determinants using CIS (Horbach, 2016) Study of firms motivations for introducing EI using CIS (Veugelers, 2012)	There are already applications of this indicator. For instance the European Commission promoted a survey to explore CE in SME's (TNS, 2016).
	Scoreboards	It presents an ensemble of key variables related to a specific subject. Difficult to interpret.	-The Eco-Innovation Scoreboard (Eco-IS) aims at capturing the different aspects of EI (EC, 2017c).	There are already applications using some of the indicator groups of the Eco-Innovation Scoreboard taking into account the principles of CE (Smol et al., 2017)

Table 16 - Innovation indicators, and their application to the sustainability and CE agenda
Source: Inspired on Galindo-Rueda and Millot (2015); Godinho(2007); Hamdan-Livramento et al. (2016)**;.** Haščič and Migotto (2015)**;** Kim and Lee (2015)**;** Mendonça (2014)**;** Mendonça and Fontana (2011)**;** OECD (2005); Patel (2006)**;** Patel and Pavitt (1995) **.**

5.3.Pro CE EI proxies: Defining a circularity assessment compass

A knowledge gap can be found as CE indicators are unaware to EI, while EI indicators overlook the "circularity" of the innovation. Considering the aforementioned innovation metrics, input indicators have clear drawbacks: they lack specificity, they alienate efforts of several actors, they neglect market acceptance. In other words, in most cases these proxies reflect intent. When focusing on their potential contribute towards assessing CE, it is found that these indicators provide no detailed information concerning the circular direction or circularity-accelerating impacts of innovation (OECD, 2017). As for the more complex indicators (surveys and scoreboards) despite enabling the possibility of comparative analysis[62] they do not transmit evolution over time (Godinho, 2007).

Output indicators, however, combine in-depth detail with the availability of extended time series and system-wide application. Moreover, they do not only reflect intent, but also market awareness and acceptance. Especially patents and trademarks, being closer to market than publications or design, may hold the largest potential for CE scanning and monitoring. Both indicators show the following characteristics:

- scalability - can be aggregated to cover firms, sectors, regions or countries;
- multidimensionality - are not narrowly defined so as to cover just a few dimensions/topics;
- modularity - may be combined with other indicators.

Patents as an indicator of technical and economic trajectories, reflect the awareness and *de facto* investment given to the protection of an invention/innovation (Moed et al., 2004, p. 215). In the last decades, the use of patent analyses and statistics to examine S&T dynamics and the processes of innovation and technical change, has become quite popular in the Academia, used in several areas of knowledge (Guellec et al., 2011; OECD, 2009b). Provided that pro-circular patents could be identified, this indicator might be useful not only to get a glimpse of CE technological progress, by technological area, but also for other considerations regarding system actors development, diffusion and application of CE strategies and their networks and collaborations. Specifically concerning pro CE innovation, two factors underline the

[62] Recently the European Commission promoted a survey to explore CE in SME's (TNS, 2016); and Smol et al. (2017) proposed an indicator based on the Eco- Innovation Scoreboard to approach the CE concept at the regional level.

potential of this proxy in the analysis. In one hand, the existence of classification schemes related with "environmental technologies" could be used to narrow down a first dataset of patents. On the other hand, the detailed and updated information in each patent enables exploring each technology's "circular characteristics". They may therefore be operationalised as a "hard" pro CE innovation proxy.

As for trademarks, this indicator related to social and cultural issues can be argued to be a good complementary indicator to other innovation pointers. Deployed to position a tangible and/or intangible good in the market, trademark applications reflect a strategic intent and economic interest (Mendonça et al., 2004a). There is already some empirical evidence showing that innovative companies are more prone to register trademarks, correlating innovation with trademark application (Mendonça et al., 2004a). Therefore, monitoring trademarks can be an important way to access goods and service innovation, in a broader range of industrial sectors, but especially in more difficult to assess sectors linked with services and SME's. Considering that marketing innovations and consumer awareness are key issues in a CE, using trademarks analysis may be a way to gauge "soft" pro CE innovation in these areas.

Appreciating the complementary nature of "hard" (new or improved goods/services and processes closely related to techno-economic trajectories) and "soft" (cultural and organisational) innovation in the transition towards a CE (de Jesus and Mendonça, 2018), how to operationalise a "focusing device" to assess an (eco)-innovation system's circular capacities and competences? The proposed answer is to combine an analysis via both those "hard" – patents - and "soft" – trademarks - indicators, within the structural components of the innovation system - i.e. context, networks and actors – to enable a comprehensive exam of its inherent dynamics and inertia (as presented in Table 17).

Innovation systems can be characterised as composed by a myriad of actors in constant interaction (competition and cooperation) that develop and diffuse innovations, impacting on technological change and economic performance (Markard and Truffer, 2008). From the outset, innovation systems literature, especially the one focusing on national innovation systems (see for instance Freeman, 1987; Lundvall, 1998; Nelson, 1993; OECD, 1997), stressed the interactions between the actors that structure systems as a dynamo of innovation or, due to constraints in those relations, a barrier to the creation and commercialisation of knowledge (Edquist, 2004). This approach recognises the importance of historical/geographical considerations and the surrounding environment to the actors of the innovation process, both with respect to the institutional constraints and the contacts with partners, competitors and consumers (Lundvall, 2007).

Indicator	***Hard*** - Technical and economic ***Patents***	**Soft** - Institutional and social ***Trademarks***
Contextual level (Macro) Identification and characterisation of trends.	- Number of "circular" patents per year - Patent trends and evolution - Competences (patent classes)	- Number of trademarks from "circular" actors per year - Trends and evolution - Competences (Trademarks categories)
Relations level (Meso) Networks and alliances. Identification of cooperation between agents (firms, industries, universities, etc.)	- Patent analysis ("circular" co-Patenting)	- Trademark application agents dynamics
Actor level (Micro) Actors knowledge development, diffusion and application of CE strategies	- Patent analysis (actors – business and companies – applicants of "circular" patents)	- Trademark analysis (actors – business and companies – applicants of "circular" trademarks)

Table 17 – (Eco) innovation systems CE analysis focusing device

In the discussion regarding EI "pro"-CE, the assessment of the contextual level, the agents' capabilities and involvement within the system, and their relations/ networks, may clarify to what extent is the system, more or less, "circular" conducive. The identification of actors'[63] capacities and relations could benefit from an analysis of patenting dynamics (main trends and key sectors; collaborations, technology intensity and dispersion) and trademarks applications (goods and services trends, sectoral dynamics, knowledge intensity). Through the diagnosis of the current "circularity" of an innovation system, bottlenecks and opportunities can be identified, which in turn help define a roadmap for furthering the implementation of a CE. CE's own nature[64], as an integrative multi-actor approach driven by synergies, makes such an assessment indispensable.

This "focusing device" can prove useful for several stakeholders. For policy-makers, an understanding of the innovation system's "circular" dynamics can assist in

[63] Scientific agents (universities and research institutes); industrial/business agents (companies, firms); and society agents (organisations, Non-governmental organisation -NGO's).

[64] Remember major contributions to CE related to eco-industrial parks, industrial ecology, industrial and urban symbiosis.

the identification of mismatches, areas to enhance performance, and limit system failures (Jacobsson and Bergek, 2011). For companies, awareness to these trends, opportunities and collaborations, enables a better organisational strategy definition, as sustainability transition and environmental awareness, or lack of thereof, can either correspond to important opportunities or constitute significant constraints. CE considerations may prove an opportunity for enterprises' positive differentiation through the development of new CE-friendly business models and increased resource efficiency. As to civil society, being included in this diagnosis may contribute to an increased awareness and realisation of its determinant role in a paradigm shift, as "demand-side actors", but also innovative agents in the development of CE.

5.4.Main Conclusions

This chapter proposes an analytical platform, an "EI circularity assessment compass", to empirically diagnose the innovation system's circularity capacities. Even if some efforts to develop and adequate indicators to CE specificities are underway, monitoring and assessing still proves a challenge, even more when trying to assess "CE-friendly" innovation. In that regard, innovation indicators could be reframed to best address that question. In particular, patents and trademarks could be "recycled" to aid in the assessment of CE dynamics, as these proxies combine *scalability* (*i.e.* can be aggregated to cover firms, sectors, regions or countries); with *multidimensionality* (are not narrowly defined so as to cover just a few areas); and *modularity* (and may be combined with other indicators).

To appreciate the dynamics and inertia of the CE, the structural components of an innovation system were used as a "focusing device" (context, actors and networks), via the dichotomy between "harder" indicators (patents) and "softer" ones (trademarks). The objective was to define an empirical approach for studying (eco)-innovation systems in the development of a CE, that could be tested in the following chapters.

CHAPTER 6

PATENTS AS A "HARD" PRO-CE EI INDICATOR

A patent is a public contract between an inventor and a government, which awards rights, for a specific period of time, regarding the use and licensing of an invention (Griliches, 1990). The invention must be novel, not trivial, and must demonstrate a significant breakthrough. In summary, it is an industrial property right to a knowledge asset on a new, non-obvious, idea (Guellec et al., 2011). Patents are filed for several motives including the prevention of imitation, blocking the dissemination of a given technology, or generating licensing opportunities (Veer and Jell, 2012). As patents' goal is to protect firms, institutions or individual inventions they are considered an indicator for invention (OECD, 2009b). The patent system can then be defined as a way to induce new knowledge, with economic interest (Smith, 2006), a way to foster investment and subsequently innovation (OECD, 2009b). Pioneer authors such as Schmookler (1972), led the way, using patents for the analysis of technological and inventive activity. Other studies streamlined the experience of patents as an economic indicator, to measure scientific and technological activities and their relation with R&D, like Scherer (1983, 1965), Mansfield (1984), or Griliches (1990). In the late 1980's further research focused on the use of patents to examine the competitiveness of countries and industries, creating revealed technology advantage indexes for various countries (Patel and Pavitt, 1995; Pavitt, 1988, 1985). More recently patents have been used as a proxy of available accumulated knowledge (Popp et al., 2011), technological change (Verdolini and Galeotti, 2011), and innovation (Diaz Arias and van Beers, 2013; Nemet, 2012; Nesta et al., 2014; Verdolini and Galeotti, 2011).

Addressing the innovation metrics agenda from the perspective of "deep sustainability" this chapter intends to discuss whether patents can be realigned to map, measure and monitor the transition towards a circular economy (CE). The objective is to operationalise an indicator of "transformational" techno-economic change, i.e. CE-inducing eco-innovation (EI). Therefore, next sections will discuss the advantages and limitations of using patents as a meaningful indicator of pro-circular innovation (Section 6.1), methodological aspects regarding data collection, organisation and analysis of data (Section 6.2) and possible empirical application (Section 6.3).

6.1.Patents as an EI proxy

The attractiveness of using patents to 'narrow' fields of technology, namely on environmental issues, derives from some of their main features and advantages regarding available information. Nevertheless, their inherent limitations also have to be taken into account. This indicator is in fact an approximation pointing to inventive activity, but not to technology adoption (Ghisetti and Quatraro, 2013). Patents also grant protection to inventions of substantially heterogeneous economic and commercial value (Griliches, 1990; Lovely and Popp, 2011; Nemet, 2012; Nesta et al., 2014; Popp et al., 2011). It must also be considered that the propensity to patent varies across countries, sectors, firms, industries and areas of activity, due to several factors. The firm size or its ability to pay and maintain the cost of a patent is determinant. Some types of actors, sectors and fields are more prone to patenting than others, like plastics, rubber, drugs and computers. Not all inventions are patentable; there are several non-patented technologies that cannot be identified in patent analyses. Even differences between countries' technological capabilities, and their enforcement of patent laws (ease of patenting; patent infringement litigation) hampers the comparability of this indicator (Diaz Arias and van Beers, 2013; Ghisetti and Quatraro, 2013; Griliches, 1990; Lovely and Popp, 2011; Miao and Popp, 2014; Nemet, 2012; Popp et al., 2011).

Still, and admittedly, patents reflect the investment in time and money that entities commit to protect an invention in the countries where they expect it to be profitable (Diaz Arias and van Beers, 2013; Popp et al., 2011). Patent data enable, therefore, a technological output assessment of national innovation systems (Neuhäusler et al., 2017). Also, patents are based on objective standards (not self-evident, novelty, usefulness) and acquiescent to statistical analysis, as they are quantitative data. Moreover, each patent has information regarding the actual invention's description, references of previous inventions (citations), inventor, inventor country, who is applying for the patent (companies, universities, individuals) and its nationality, country of patenting, among other interesting data. Furthermore, patent information is also organised through standardised classifications schemes, which permit to circumscribe specific technological areas. Finally, only very few economically significant inventions have not been patented (Diaz Arias and van Beers, 2013; Griliches, 1990; Lovely and Popp, 2011; Mendonça, 2009; Nemet, 2012; Popp, 2005; Popp et al., 2011). As a result, considering the advantages of the “patent” indicator, the question is how to operationalise this data as a proxy of CE-inducing technical change.

6.1.1. Existing EI patent classifications

In the specific subset of environmental technologies, one of the major difficulties, while using patent analysis, is that they tend to intersect several categories, not falling under only one single dedicated classification scheme (EPO et al., 2010). That is, identifying patents in a narrow field using the existing system would imply too much “noise” and incomplete information. In regard to “green technologies”, this issue is linked with a definitional problem. Unfortunately, there is still no commonly accepted definition on technologies with ecological attributes; the terminology itself is fluid. Even if several countries (among others the United Kingdom, the United States, Australia, Korea, Japan, Israel, Canada, Brazil and China) have implemented fast-tracking measures for “green” patent applications (Dechezleprêtre, 2013) there are several different definitions of what constitutes a “green” patent application. Most patent offices use a broad and vague definition, requiring only that the applicant declares the “environmental” benefits of the invention (AIPPI, 2014), even if the OCDE has attempted to define a “green patent”[65] (OECD, 2011a). As the definition of which technologies are considered “environmental” evolves over time, the meaning of what is a “green patent” will also have to be adapted (OECD, 2013).

Against this background, a number of classification schemes and indexes concerning “green” patents have been promoted to improve the identification of patents in this “narrow” field. Three major contributions have been deployed by international organisations particularly focused on patent applications, like the European Patent Office, the World Intellectual Property Organization and the OECD. Table 18 details the initiatives which were considered as possibilities for a pro-CE technological EI analysis.

[65] Including “environmental patents” in areas like waste management, air and water pollution reduction, renewable energies, hybrid/electric car technologies and energy efficiency in lighting and building (OECD, 2011a).

Patent catchword	Description of content	Initiative
“Sustainable technologies” (Y02 scheme)	- Y02B. Buildings, i.e. environmental impact mitigation technologies related to the construction of buildings, construction elements, appliances, integration of renewable energy sources, etc.; - Y02C. greenhouse gases mitigation, i.e. greenhouse gases capture and storage/sequestration or disposal technologies; - Y02E. energy generation, transmission or distribution; Y02P. production or processing of goods, i.e. industrial processing or production activity, including the agro-alimentary industry, agriculture, fishing, ranching, etc.; - Y02T. transportation, i.e. ways to reduce emissions of greenhouse gases from goods and persons transport; - Y02W. waste, i.e. waste processing concerning solid and waste water treatment, and reuse, recycling or recovery technologies.	EPO, following cooperation with UNEP and ICTSD. Prepared for the Copenhagen Conference of Parties (COP) of 2010.
“Environmentally sound technologies”	- Alternative energy production. - Transport. - Energy conservation. - Waste management. - Agriculture/Forestry. - Administrative, regulatory or design aspects. - Nuclear power generation.	“Green inventory”. WIPO’s effort to facilitate search of technologies listed by the United Nations Framework Convention on Climate Change (UNFCCC).
“Green patents”	1. Environmental management technologies; 2. Water-related adaptation technologies; 3. Biodiversity protection technologies; 4. Energy; 5. Greenhouse gases; 6. Transport; 7. Buildings; 8. Wastewater treatment and waste management; 9. Production or processing of goods	“Green Growth Indicators”

Table 18 - Patent classification schemes for tracking environmentally-friendly technological innovation

Note: Inspired on EPO (2016); EPO et al. (2010); OECD (2017, 2016); Veefkind et al. (2012); WIPO (2012).

First, in 2009, the United Nations Environment Programme (UNEP), the European Patent Office (EPO) and the International Centre for Trade and Sustainable Development (ICTSD), initiated the work on a new patent tagging scheme for climate change mitigation technologies (CCMTs, or “sustainable technologies”), to be included and regularly updated in EPO’s Worldwide Patent Statistics Database (PATSTAT) (Barbieri, 2016; EPO, 2016; EPO et al., 2010; Kılkış, 2016a; Veefkind et al., 2012).

This new categorisation was released at the Copenhagen Conference of Parties (COP) and at the Bonn UN Climate Change Talks of 2010 (EPO et al., 2010) yielding a consolidated scheme available for searches, the Y02. This scheme, which is a supplementary nomenclature to standard ones like the International Patent Classification

(IPC)[66] and the European classification system (ECLA)[67], became a basis for a comprehensive, detailed and regularly updated database acknowledged by official international stakeholders, but accessible to non-expert users (Veefkind et al., 2012). Since 2017 it comprises six categories referring to “environmental technologies” including transport and building, energy and emissions, primary and secondary sectoral activities, solid and liquid waste.

Second, the World Intellectual Property Organization (WIPO) carried out a project in 2010 that aimed at facilitating the searches of so-called “environmentally sound technologies”[68], as defined by the United Nations Framework Convention on Climate Change. This was made under the umbrella of the “Green inventory” (WIPO, 2012). This scheme is, nevertheless, difficult to use. The information is not easily accessible, implying a considerable degree of know-how and time from users to retrieve the information without many false hits (Veefkind et al., 2012).

Third, and since March 2015, the OECD launched the “Green Growth Indicators” initiative. The key idea was to make available data to assess the quality of growth, by becoming more efficient in resource use, in generating new opportunities, and in maintaining the natural asset base while bringing benefits for the people. Under this project the OECD publishes a new set of “green patents” (also named “environmentally-related”) statistics (OECD, 2017, 2016). Based on the IPC, the OECD in collaboration with universities, research institutes and patent examiners at the EPO, developed a new classification scheme. This scheme draws heavily on the Y02 classification, and has been refining over time (it integrated two other areas to the Y02, namely environmental management and water management technologies see Haščič et al., 2015).

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[66] *International Patent Classification* (IPC) was established by the Strasbourg Agreement 1971 and provides a classification of patents and utility models according to the different areas of technology (WIPO, 2014), it has approximately 70,000 description codes of inventions, depending on their characteristics and technical areas (EPO, 2010).

[67] The *European Classification* (ECLA) is a patent statistics classification system that extends the IPC classification system. It has around 140 000 subdivisions and is in permanent update and review (EPO, 2010). ECLA was replaced by the Cooperative Patent Classification (CPC) as of January 1, 2013 (EPO, 2013; Haščič and Migotto, 2015).

[68] “Technologies that protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes and are compatible with nationally determined socio-economic, cultural and environmental priorities” (Klein et al., 2006, p. 12).

Although with inherent specificities, all those indexes and classification schemes are in line with the broad EU definition of EI as "any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development" (EC, 2011a, p. 2). And indeed, all have been used as proxies in the study of EI, to further measure innovation in climate and other environment-related technologies (in the case of the Y02 see for instance Barbieri, 2016 and Kılkış, 2016a; regarding "green patents" see Haščič et al., 2015); and to assess innovation policies (considering the "green inventory" see for instance Fabrizio et al., 2017; Kılkış, 2016b).

6.1.2. Towards a "circular" patent

If the identification of an innovation proxy for EI assessment could be "easily" sought, finding a "pro"-CE EI indicator presents a greater challenge. Not all technologies identified in any of the aforementioned datasets could surely be considered "circular". Bearing in mind CE's holistic diversity, its assessment cannot be exclusively dependent on green patents, but instead "pro-CE characteristics" have to be considered. Therefore, if patents can be operationalised as an indicator of "transformational" techno-economic change, i.e. CE-inducing technological EI, such operationalisation would have, first, to consider what a "circular patent" may be (what are the pro-CE characteristics?), and, secondly, how best patent dynamics can be assessed (what trends and turns are revealed).

Grounded on previous work on CE definition (see Chapter 2), CE is characterised as a way to reorganise systems, to alter and redesign consumption patterns. It has a "close the loop" focus and a "reconceptualise waste" aim. In this regard, three main characteristics, encompassing all life cycle, standout in the literature concerning CE's emphasis on: 1) Input minimisation and efficient use of regenerative resources; 2) Life cycle extension and systems reconceptualization; 3) Output reduction, valorisation and waste minimisation (Table 19). Assessing if a patent has, or not, CE characteristics should therefore consider those main features as "circularity criteria". As a result, an EI patent could be categorised, according to the criteria, as having none, one, or several, of those "CE characteristics".

For this study, the Y02 classification system was selected as the data source for finding *potentially* pro-CE technological EI. One reason for this choice was *expediency*:

the classification already exists, is updated regularly [69], is still under-exploited, and allows data to be identified even by non-specialists. A second reason was *effectiveness*: work on this raw data by intellectual property office experts produced a consistent long series of multi-disciplinary patent records that are easily retrievable in databases like Espacenet[70] and PATSTAT.[71] A third reason was conceptual *coherence*: no core component of the CE definition happens to be left blank by the Y02 meta-list of patent classes (Table 19).

Key CE characteristics	Y02
Input minimisation and efficient use of regenerative resources - Material consumption reduction. Technologies that enable: reducing the consumption of materials and energy; using less material-intensive options, prioritising the use of renewable and non-hazardous materials. **Life cycle extension and systems reconceptualization -** Extension of life. Technologies that enable: the use/production of durable materials/products; the expansion/ optimisation of product lifespan; the optimisation of the use of resources throughout the product life cycle; the reconceptualization of products to greater lifecycles from the outset (namely using eco-design); that facilitate maintenance; increase traceability for reverse logistics; the development of repair, reconditioning and remanufacturing options; the improvement of materials recycling; automation and digital supports to new business models (from products to services, performance savings, sharing and leasing, etc.). **Output reduction, valorisation and waste minimisation -** Elimination, valorisation or reduction of waste. Technologies that enable: the prevention of waste or the "design out" of waste; more efficient management or recycling of waste that cannot be reused or remanufactured.	• **Y02E.** energy generation, transmission or distribution • **Y02P.** production or processing of goods, i.e. industrial processing or production activity, including the agro-alimentary industry, agriculture, fishing, ranching, etc. • **Y02T.** transportation, i.e. ways to reduce emissions of greenhouse gases from goods and persons transport • **Y02B.** Buildings, i.e. environmental impact mitigation technologies related to the construction of buildings, construction elements, appliances, integration of renewable energy sources, etc. • **Y02C.** greenhouse gases mitigation, i.e. greenhouse gases capture and storage/sequestration or disposal technologies • **Y02W.** waste, i.e. waste processing concerning solid and waste water treatment, and reuse, recycling or recovery technologies

Table 19 - CE three main characteristics and Y02 classification correspondence[72]

[69] For instances, since our analysis (in January 2018) this classification had a further extension with two new subclasses: Y02A "Technologies for adaptation to climate change" and a Y02D "Mitigation technologies in information and communication technologies".

[70] Espacenet is a free online service by the EPO, updated daily, holding data on over than 90 million patent documents from around the world (EPO, 2017a).

[71] PATSAT is the WIPO's statistical database for patents. Aimed at patent information specialists, companies, patent attorneys and academics, it is available as a web-based interface enabling statistical retrieval (EPO, 2017b).

[72] In January 2018 there was a further extension of the Y02 that have now two additional sub-classes: Y02A "Technologies for adaptation to climate change" and Y02D "Mitigation technologies in

Hence, considering the advantages of the Y02 scheme over alternatives, in terms of simplicity and accessibility, the search strategy presented in this work relied on this classification scheme so as to solve the operational concept-data nexus, i.e. Y02 meta-classes are taken to indicate technological learning and achievement in EI (de Jesus and Mendonça in UN, 2015, p. 90). Equating Y02 to *potentially* pro-CE technological EI just reduces the search space for finding *actually* pro-CE technological EI. Next section explains how to build from here.

6.2.Methodological considerations

Table 20 synthesises the research steps regarding data collection and analysis that will be fully clarified in the following sub-sections. The data acquisition techniques are explained, as well as the criteria to select the sample. Every single patent in the sample was handled manually, read and matched to the CE grid characteristics.

Step	How to access EI "circularity"?
DATA COLLECTION	**Patents as a pro-CE "Hard" EI indicator in Portugal:** ▪ Use of Y02 classification scheme ▪ Espacenet search ▪ Y02 patents with inventor AND/OR applicant PT ▪ Time span (priority date) 1990-2015 ↓ *After data cleaning (duplication elimination) – 401 patents*
VALIDATION OF METHOD	**Sample selection and inclusion/exclusion codes validation of pro-CE technological EI:** ▪ Only patents with two or more Y02 classes were chosen ▪ Sampling procedures identified 54 patents ▪ Content analysis of Sample : Latent analysis of the patent document ▪ Expert's validation –Building a balanced pool of experts and getting their feedback (Codification by external coders) ↓ *Agreement between coders and experts 85% (Validation quality)*
CODIFICATION	**Content analysis applied to the total 401 patents:** ▪ Computer-aided (NVivo assisted) analysis of the patent document according with the identified codes 1) "Input minimisation"; 2) "Life cycle extension" 3) "Output reduction"; 4) EI without circular economy characteristics (WCEC); or 5) Not identifiable (N/I) ↓ *Y02 patents with pro-CE characteristics: 65%*
DATA ANALYSIS	**Y02 with CE characteristics analysis concerning:** ▪ EI evolution (How many patents per year) ▪ EI technological dispersion (Sub types of Y02) ▪ Actor identification (Which are the main organisations -universities, companies?) ▪ Cooperation between agents (partnerships between organisations)

Table 20 - Patent's research design

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information and communication technologies". Both these sub-classes were not included in the present analysis.

6.2.1. Data Collection

Espacenet, as compared to other patent databases, allows for the easy retrieval of information. This source provides access to the "Abstract" and "Description" of the patent's "Original Document", information essential to individually evaluate if a patent would fall within the scope of CE (as ultimately patents had to be analysed individually to ascertain of its CE characteristics). Hence, search queries were carried in Espacenet[73], for Y02 patents, with first priority date between 1990 and 2015, and Portuguese inventor and/or applicant. As patents specific readouts are dependent on the search criteria, some reflections about those choices, namely about chronological time span, geographic considerations, and patents status, are due.

Regarding the chronological time span, public and governmental awareness to the detrimental effect of environmental degradation emerged during the last third of the 20th century. Momentum was gained particularly after the 1990s with the 1992 UN Conference on Environment and Development (UNCED) in Rio de Janeiro (ONU, 1992). In addition, harmonisation of patent offices' routines just happened from the early 20th century onwards (Lerner, 2005). Consequently, chronologically, this research includes patents with the earliest priority date from 1990 onward since, before this date, less observations were to be expected.

The "priority date" was chosen as it is the date closest to the invention (Table 21), and highly recommended in order to reflect inventive performance (OECD, 2009b). It must, nevertheless, be used carefully to avoid biased interpretations. As applications are published at least 18 months after filing,[74] and must be kept secret before publication (EPO, 2013; Haščič and Migotto, 2015), it is normal to see a dip in filings especially in the last 2 years of the sample (known as "publication lag"), due to the lack of available data on the non-published applications[75]. This can explain, for instance, the slight depression in the 2015 number of patents.

[73] http://worldwide.espacenet.com – Search last updated on 13 April 2017.
[74] However, a bigger delay is possible, since patent authorities may take more time to send EPO the information about applications.
[75] This explains why 2016 patents do not show in the search and also point to the need to carefully consider the 2015 data.

Earliest priority date	Date of the first publication
• Reference for the requirement of patentability: This is the date closest to the act of invention	• When the patent is made available to the public
• Reflects R&D activities of companies and institutions.	• Applications are published 18 months after filing and must be kept secret before publication. However, a bigger delay is possible.

Table 21 - Patent analysis: which date to choose?
Note: Inspired on Guellec et al. (2011) Moed et al. (2004)

As for the use of patents with a Portuguese inventor or applicant (Table 22), the intention was to gather information regarding innovative performance trends of a concrete country and the web of its organisations (that is, a national innovation system). The Portuguese case was chosen as it is an interesting international example in the context of knowledge evolution and industrial change (Teixeira et al., 2014). In the current globalised world, afflicted by an adverse and turbulent economic climate and an ecological environment subject to high pressure, Portuguese environmental and innovation policies have been oriented to "catch-up" to the EU political agenda. Portuguese economy is still fragile, facing great challenges regarding overcoming anaemic economic development and serious structural problems, such as excessive public and private indebtedness, lack of international competitiveness and low national productivity (Costa et al., 2016). Regarding EI, Portugal is considered "moderately" innovative (Santos, 2016) registering some important advances in clean energy, climate change mitigation and the development of national waste management strategies (EIO, 2014). CE has been increasingly brought to light in the Portuguese policy arena (Government of Portugal- Ministry of Environment, 2017a, 2014, 2016) with several initiatives being developed to stimulate and promote CE[76]. The Portuguese Circular Economy Action Plan (PAEC) was also just recently approved, in November 2017 (Government of Portugal- Ministry of Environment, 2017a), after other European counterparts have already started implementing such plans (EMF, 2016a; Government of Netherlands, 2016; State of Green, 2016). Being an example of a small country in need of relaunching its economic competitiveness and environmental performance,

[76] For instance the Eco.nomia platform, launched in 2016, that intended to divulge the advantages and opportunities of the CE (Government of Portugal- Ministry of Environment, 2017b).

Portugal does seem an apt case to test the use of patent data in gauging the technological EI progress towards CE.

Country of applicant	Country of inventor	Patent office country
• Focus on "ownership" (patents owned by residents of a given country).	• Focus on innovative performance.	• Focus on the attractiveness of a country's patenting process.
• Addresses the innovative performance of a country's applicants (regardless of where the research was done).	• Addresses researchers resident in a given country.	• Enables considerations regarding the quality of intellectual property regulations, cost of patenting of the patent office, and general economic features (size/importance of the market).

Table 22 - Patent analysis: inventor, applicant or country
Note: Inspired on Guellec et al. (2011) and Moed et al. (2004)

Finally, the dataset included all patent applications, counting however only the oldest patent within a patent family (as to avoid patent duplication). The use of patent applications enabled gathering the most recent information (avoiding outdated data) and the inclusion of a broad set of inventions (diversity) (Dachs and Pyka, 2010). Overall, the resulting dataset, last updated on April 2017, gathered 401 documents for the period 1990-2015.

6.2.2. Content analysis: Defining coding criteria

To explore patent information, and in order to ascertain "circular characteristics", content analysis techniques were applied (Bengtsson, 2016; Krippendorff, 2003; Patton, 2001). A content analysis is a method to evaluate a corpus of qualitative data through codification of its explicit and latent meanings. The focus of content analysis is on the systematic examination of documents using explicit rules in order to achieve an objective and replicable analysis (Krippendorff, 2003). It has been increasingly used over the last decades, due to the dissemination of text processing programs, in a widening number of fields, particularly in the social sciences (Krippendorff, 2003). It is, moreover, an accepted method to inquire patent data, including from the perspective of empirical legal research (Curran, 2013; Lim, 2013).

Here, a latent analysis was geared at the interpretative analysis of the patent "Description",[77] in a deductive way (Bengtsson, 2016). That is to say, the analysis was performed to find the underlying meaning of the text using a defined coding list (see Sub-section 6.1.2, inspired on the CE literature review- Chapter 2). The content coding process was initially conducted on a sample of 54 patents and after validation (see section 6.2.3) expanded to all the 401 patents using the NVivo11[78] software platform.

The coding criteria distinguished between *inclusion* and *exclusion* conditions. The inclusion criteria used the three main CE characteristics previously identified. An EI patent could be categorised, according to that criteria, as having none, one, or several, of those "CE characteristics"[79]. As for the exclusion criteria (i.e., characteristics of "non-circular" patents) two codes were defined: patents "without circular economy characteristics" (WCEC) including technologies that do not have CE characteristics; and "not identifiable" (N/I) when a patent document does not allow any categorisation (sometimes lacking information or the original abstract and description) - Table 23.

The identification of those codes complied with two main objectives: on the one hand, avoid "false positives" - the classification of a technology as having circular characteristics, without being so; and, on the other, prevent "false negatives" i.e. the rejection of technologies with circular characteristics. These criteria intended to be neither too broad (a patent that meets one criterion does not necessarily meet another), nor too narrow (a patent may be inscribed in a single inclusion criterion or in more than one). Each inclusion and exclusion criterion is further described and characterised in Table 23, and examples of actual patents are provided to demonstrate the way the codes were applied.

[77] The "description" of the patent was preferentially used instead of the "abstract", even implying a greater workload. This choice was taken considering the inherent limitations of the "patent" documents as these are intrinsically complex (so that the information is not easily understood and emulated by competitors). The little information provided in the abstract was not considered sufficient to enable a clear definition.

[78] Nvivo11- Qualitative data analysis software; QSR International Pty Ltd. Version 11, 2015.

[79] In order to avoid duplication, when a patent falls into more than one criterion, it is weighted accordingly (for instance, if it falls on the criteria 1 and 2 it counts 0,5 in each criteria).

	Criteria	Definition	Elements	Examples of patents
Inclusion Criteria	**1.“Input minimisation and efficient use of regenerative resources”**	Material consumption reduction. Technologies that enable: reducing the consumption of materials and energy; the use of less material-intensive options, prioritising the use of renewable and non-hazardous materials.	Energy efficiency and energy savings	“Present invention makes it possible to move modular constructions, for example houses, according to the solar orientation, in order to make them energy efficient.” Patent with the priority number PT20120106514 20120831
			Reduce non-renewable resources/ materials consumption	“The present invention relates to the increasing need to reduce both energy, raw material and waste resulting from the use of discarded clamps, and the limitations of previous reusable clamps.”[80] Patent with the priority number: PT20120106674 20121127
			Renewable energies	“Solar energy to heat water for domestic or industrial use (…) as a source of renewable energy that reduces dependence on energy produced through non-renewable sources”[81]. Patent with the priority number: PT20120106557 20120928
	2.“Life cycle extension and reconceptu-alization”	Extension of life. Technologies that enable: the use/production of durable materials/products; the expansion/ optimisation of product lifespan; the optimisation of the use of resources throughout the product life cycle; the reconceptualization of products to greater lifecycles from the outset (namely using eco-design); facilitate maintenance; increase traceability for reverse logistics; the development of repair, reconditioning and remanufacturing options; the improvement of materials recycling; automation and digital supports to new business models (from products to services, performance savings, sharing and leasing, etc.).	Reuse	“The possibility of introducing this element and its components into one building and, in the future, be able to reuse them in another application is a basic aspect of the Liquid Integrated Accumulator concept. Thus, it will be possible to apply in a building A and later remove and reuse it in a building B.”[82] Patent with the priority number: PT20090104827 20091117
			Optimisation (durability, modularity, etc.)	“The invented system is modular and is in the form of a kit of simple parts to be assembled and disassembled “[83]. Patent with the priority number: PT20090104408 20090206
			Reconceptu-alization of products/ Eco-design	“The invention places the panels under the surface of the roof and replaces, in the area occupied by them, the ceramic tiles by exactly the same tiles, but of transparent glass, already used for the execution of skylights. (...) The resulting visual impact is minimal, so the aesthetic integration of solar panels is no longer a problem”[84] Patent with the priority number: PT20100010588U 20100614

[80] In the original “A presente invenção diz respeito à crescente necessidade em reduzir consumos, tanto energéticos como de matérias-primas, contrapondo o desperdício resultante da destruição das braçadeiras conhecidas para fixação definitiva e as fragilidades presentes no estado da técnica das braçadeiras reutilizáveis já citadas.”

[81] In the original “Energia solar para aquecer água para uso doméstico ou industrial. É uma fonte de energia renovável e reduz a dependência da energia eléctrica que é produzida através de fontes de energia não renováveis”.

[82] In the original “A possibilidade de introduzir este elemento e os seus componentes num edifício e, no futuro, poder reutiliza-los noutra aplicação é um aspeto base do conceito do Acumulador Integrado Liquido. Assim, será possível aplicar num edifício A e mais tarde retirar, e reutiliza-lo num edifício B”

[83] In the original “Le système inventé est modulaire ; il se présente, en pratique, sous la forme d'un kit de pièces simples à monter et à démonter en suivant un séquençage”.

[84] In the original “Com o sistema objecto do invento coloca os painéis sob superfície do telhado e substitui, na área por eles ocupada, as telhas cerâmicas por telhas exatamente iguais, mas de vidro transparente, já utilizadas para a execução de claraboias. (…) O impacto visual resultante é mínimo, portanto a integração estética dos painéis solares deixa de constituir um problema”.

Inclusion Criteria (Cont.)	**3.“ Output reduction, valorisation and waste minimisation”**	Elimination, valorisation or reduction of waste. Technologies that enable: the prevention of waste or the “design out” of waste; more efficient management or recycling of waste that cannot be reused or remanufactured.	Recycling	“Process consisting of the aggregation of several products destined for landfills, which in the end gives rise to a processed product that replaces wood in various applications”[85] Patent with the priority number: PT20120011138U 20120910
			Waste as input/ Waste valorisation	“The invention is a process which uses waste from the cork sector, namely cork dust (...) mechanically or manually mixed with the effluents and / or waste from the olive oil production units giving rise to a slurry that can be used as fertilizer and which, alternatively, after drying, can be targeted for energy recovery.”[86] Patent with the priority number: PT20060103470 20060428
			Pollution mitigation	“[advantages of the process] i) the process effectively decreases the carbon 'footprint' (i.e. tons CO2 generated per ton red mud), as decreasing the moisture in the melt reduction furnace 31 means that less coke breeze will be required and so, in turn, generating less carbon dioxide” Patent with the priority number GB20070021485 20071101
Exclusion Criteria	**4.Without circular economy characteristics (WCEC)**	EI technologies that do not have CE characteristics. Technology is eco-innovative but do not have material/energy, waste valorisation, or life cycle extension characteristics		“Displacement of people and equipment in wind towers, enabling their vertical and horizontal translation around the tower and the blades” Patent with the priority number:PT20120010845 20120720 - This technology focuses an easier and safer dislocation of people and equipment in a wind tower. It is outside the scope of CE strategies
	5.Not identifiable (N/I)	Lack of information in the patent. Cases where the original document is missing or when the information in the Abstract and/or Description does not allow a categorisation		

Table 23 - Inclusion and exclusion criteria

It must be underlined that the criteria were defined seeking to identify EI patents with “circular characteristics”, as a proxy for “circular” EI. Patents are only technology “on paper”, not in practice; they *point to* technological capabilities not to actually demonstrated knowledge of innovative development deployed in a usage context. By the very own characteristics of the patenting process (a too detailed description in a patent can be overly informative for competitors and can also narrow the protective scope of the invention) patent technical texts have features that are normally difficult to understand and read (regarding this subject see for instance Moed et al., 2004, p. 671).

85 In the original “Processo que consiste na agregação de vários produtos com destino a aterros sanitários, que no final origina um produto transformado que substitui a madeira em várias aplicações”.

86 In the original “A invenção consiste num processo que utiliza os resíduos do sector da cortiça, nomeadamente pó de cortiça (…) misturados de forma mecânica ou manual com os efluentes e ou resíduos das unidades de produção de azeite dando origem a uma lama ou pasta que pode ser utilizada como fertilizante e que, alternativamente, após secagem, pode ser alvo de valorização energética”.

Patents offer only a very limited insight on the "degree of circularity"; therefore, considerations regarding if a patent is *more* or *less* circular could not be sought here. The purpose of this exercise is mainly to identify EI patents with circular characteristics; not to appreciate the degree of circularity of those characteristics.

6.2.3. Sample and Validation

For the sake of an in-depth analysis of the 401 patents (and as the number of patents prevented the possibility to do this to all of them) a preliminary sample was identified, codified and a participatory approach used to validate the criteria and codification. This triangulation procedure intended to limit researcher biases (there is always an implicit risk of different researchers getting different information from the same dataset) and sought to increase the validity on the following attribution of codes (Bengtsson, 2016). There is, nevertheless, no unique set of criteria to determine the size of a representative sample (Bengtsson, 2016). The insights gathered from the literature point to the selection of observations being more important than the number of cases chosen (Patton, 2001). Thus, the sample size must rely on the requirements necessary to answer the research objectives with sufficient confidence (Krippendorff, 2003; Patton, 2001).

As the main drive behind this chapter is to identify EI patents with "circular characteristics", the preliminary sample was identified by choosing, among the 401 patents, all the Y02 with more than one class (i.e. at least two out of the Y02B, Y02C, Y02E, Y02P, Y02T, and Y02W). The objective was to rapidly identify a sample of informationally rich and more cross-cutting EI patents with more holistic characteristics. This enabled the identification of a sample of 54 patents, containing examples of all the timeline, Y02 subtypes, and applicant types. The structure of the patent population is preserved in the patent sample (Table 24). This procedure is not taken as a guarantee that the filtered EI patents are in fact pro-CE. That step is a further one, which implies a deeper level of analysis, using the very content of the patent document (as it was discussed in 6.2.2).

Time period	Y02 Total	Y02 Sample	% of Total
1990 - 1995	10	1	10%
1996 - 2000	22	1	5%
2001- 2005	48	6	13%
2006 - 2010	200	28	14%
2011 - 2015	121	18	15%
Total	401	54	13%

Table 24 - Number of sample patents per period and % compared to total Nº of Y02
Note: Elaboration on the patent corpus

The sample was first codified and then independently reviewed by external specialists (a total of 11). These experts came from several backgrounds (engineering, management, etc.), distinct institutional affiliations (academic, public, and private sectors), and different geographic regions (all hemispheres), although mainly from Portugal (Table 25). To calibrate and better adjust the criteria these same specialists were invited to comment on them. The overall inter-rate agreement between the coders in the sample was of 87%. Discrepancies and criteria feedback were discussed with the experts and conclusions drawn included in the final version of the criteria.

Disciplinary background	Nº of reviewers	Position	Nº of reviewers	Sector	Nº of reviewers	Country of Work	Nº of reviewers
Economics and management	3	Policy Adviser	3	Academic	5	Brazil	1
Energy and environment engineering	5	Professor	4	Private	1	China - Macao	1
Scientific and technological policy and administration	3	Researcher	4	Public	5	Colombia	1
						Germany	1
						Mexico	1
						Portugal	6

Table 25 - Sample validation with specialists

6.2.4. Data analysis

Building on the information gathered from the validation step, the rest of the patents were analysed and the criteria applied to the overall 401 patent applications. Ultimately, 260 patents with "circular characteristics" were identified (around 65% of the total 401 Y02). Patents were analysed in excel-based software concerning global trends, comparing overall Y02 patents findings with Y02 with "CE" characteristics. Final data was afterwards examined using as "focusing device" the structural components of a national innovation system, i.e. context and aggregate performance (how many patents with CE characteristics per year; Y02 subclasses); actors and links between scientific (universities and research institutes), industrial/business (companies) and other actors. Next section presents and discusses the results from the data analysis.

6.3. Innovation systems in deep transition: What do "circular patents" tell?

6.3.1. Major trends in Portuguese EI patenting

The overall patenting activity in Y02 technologies enables a glimpse on the evolution and dynamics of Portuguese EI advancements. These may be useful to measure intentions to economically exploit these technologies according to the emerging demand and growing attention to environmental issues (Figure 13). In the early 1990s, despite the growing importance of sustainable development issues, with the Brundland Our Common Future Report of 1987, the 1992 Earth Conference in Rio de Janeiro and Kyoto Protocol in 1997, Y02 patenting is still rather limited. Nevertheless, considering that in 1990 the overall number of patents applications in Portugal amounted to a total of 148 patents[87] the small number of Y02 can be argued to be in line with the low technological performance of the Portuguese economy as a whole at the time (Teixeira et al., 2014).

[87] Source INPI/MJ, PORDATA (Access 12.06.2017).

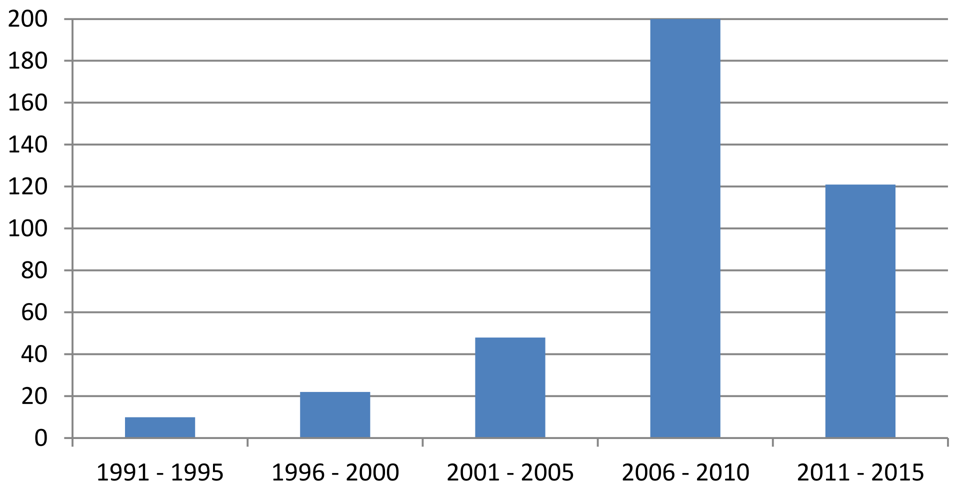

Figure 13 - Y02 patents trends (5 year period)
Note: Elaboration on the patent corpus; applies to all tables and figures in the chapter from now on, unless otherwise stated

The momentum seems to be gained decisively around the year 2000 with a growing upward trend. While in the previous five-year period (2001-2005) the annual average was 9.6 patents per year, between 2006 and 2010 the average number of patents per year jump to 40. This positive trend was interrupted after 2010, possibly as a result of the impact of the global financial crisis on the Portuguese economy which ultimately led to a severe debt crisis and a bailout from the 'Troika' of the European Commission (EC), the European Central Bank (ECB) and the International Monetary Fund (IMF) in April 2011 (Costa et al., 2016). Tentatively, the number of patents has been on the rise again from the end of the 2011-2015 period, but still rather far from the previous five-year interval.[88]

6.3.2. The emergence of EI with CE characteristics

Within the overall 401 patent applications, the 260 Y02 patents "with CE characteristics" can be highlighted (Figure 14). There is a rise since 2000, and robust growth until 2010, but a decrease after that.

[88] It should be noted, however, that although this review uses the priority date of the patent, the public disclosure of patent data happens when it is published, about 18 months after the priority date (depending on the patent authorities themselves). This question determined that the years of 2016 and 2017 could not be used in this analysis. However, it is also necessary to reiterate that the data regarding 2015 may be underestimated (EPO, 2010).

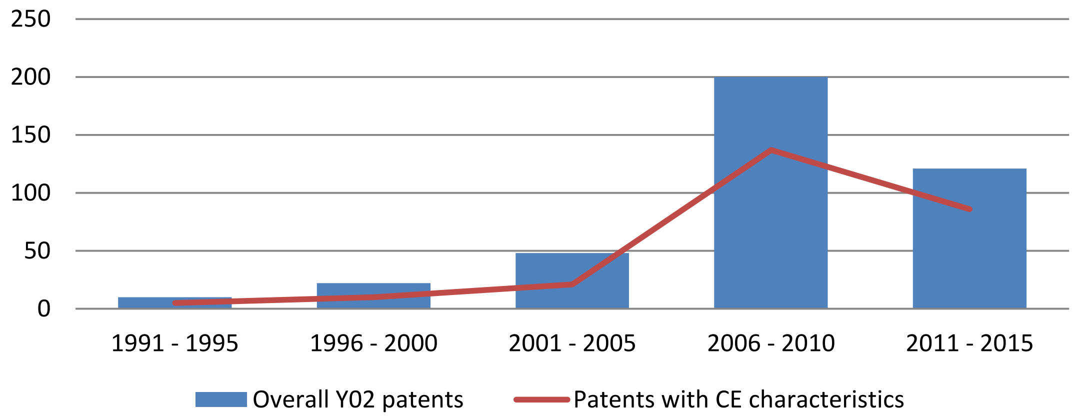

Figure 14 - Overall Y02 and Y02 with CE characteristics – Trends (5 year period)

It is nevertheless interesting to note that, despite the overall decrease in patent filings, the percentage of patents identified with CE characteristics increased, from 69% in 2006-2010 to around 71% of the overall of Y02 patents in the period of 2011-2015 (Figure 15). This may account for a slight increase in awareness and interest in EI encompassing CE strategies. Nonetheless, the proportion of patents without CE characteristics (WCEC) is still arguably high (Table 26). This must be considered when using this indicator as a proxy for CE development.

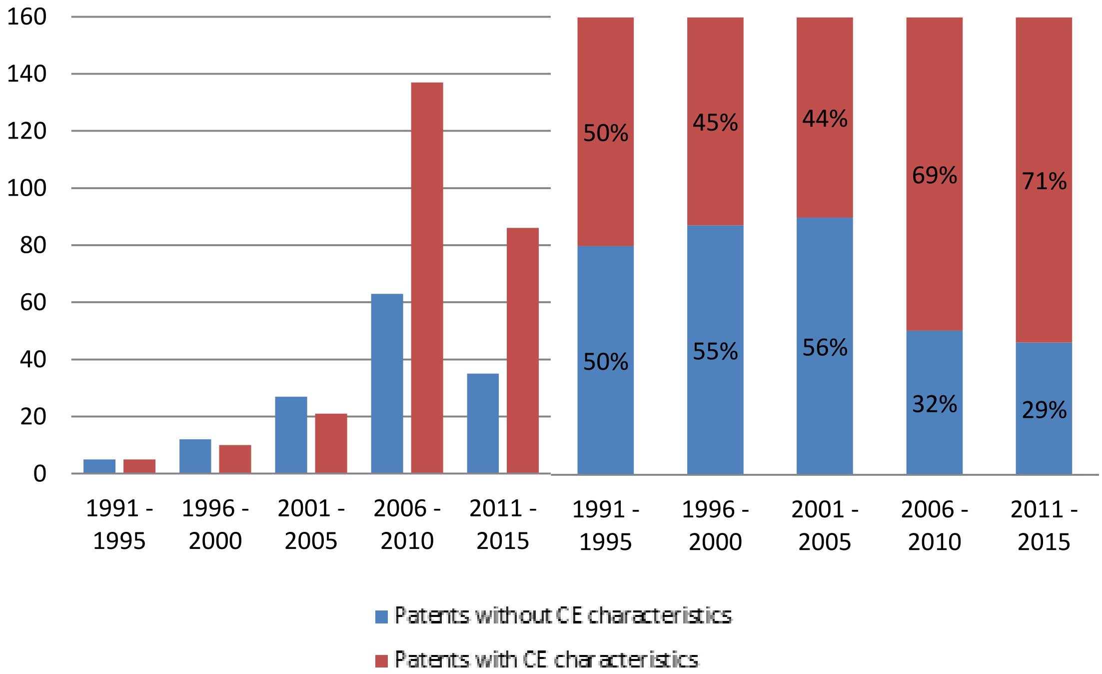

Figure 15 - Y02 with and without CE characteristics – Total and %

	Input minimisation [1]	Life cycle extension [2]	Output reduction [3]	Without circular economy characteristics (WCEC)	Not identifiable (N/A)
1991 - 1995	50%	0%	0%	20%	30%
1996 - 2000	9%	2%	34%	23%	32%
2001 - 2005	19%	3%	22%	35%	21%
2006 - 2010	40%	12%	16%	30%	2%
2011 - 2015	49%	9%	13%	27%	2%

Table 26 - Y02 per inclusion and exclusion criteria

Notwithstanding the limitation, it is possible to get a glimpse on the evolution regarding the key CE characteristics defined earlier: the “input minimisation” category unyieldingly dominates (Figure 16). Input minimisation and the efficient use of regenerative resources accounts for the most part of the “CE” patents in all time periods. This may reflect the developments on energy policies carried out in Portugal since the mid-1990s (Araújo and Coelho, 2013). The ratification of the 1992 United Nations Framework Convention on Climate Change was the first legislative and political act related to climate change in the country that signals an increased importance of the energy sector (Araújo and Coelho, 2013). In 2005 the implementation of the “Technological Plan” and of the “Strategic Energy Plan” reinforced this trend. Also, in 2010, the “National Energy Strategy” aimed to achieve a reduction of 20% in energy consumption by 2020 and the consolidation of a renewable energy cluster through fiscal measures and incentives for innovative projects, further stressing the focus on renewable energies and the promotion of energy efficiency in Portugal (RCM 29, 2010). In 2009, Portugal ranked third in the EU-15 in terms of the proportion of renewable energy in total electricity produced, and between 2003 and 2010, the installed capacity of renewable energy almost doubled (Fontes et al., 2012, p. 18). More recently, in 2016, the Portuguese economy ran for 107 hours exclusively on electricity from renewable sources (CNN, 2016).

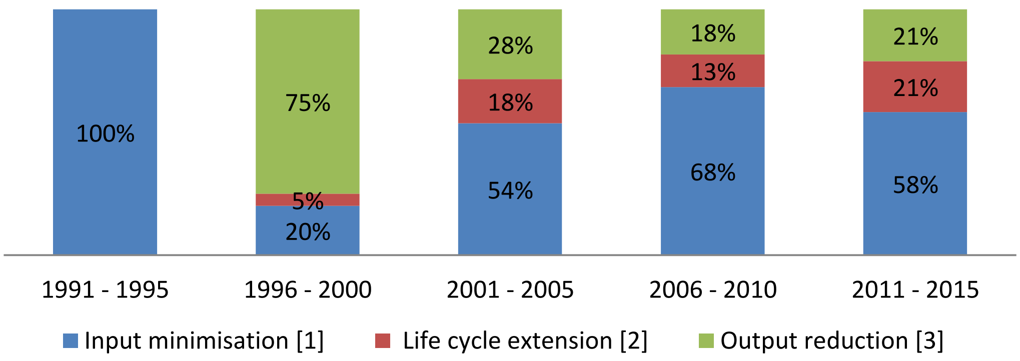

Figure 16 - % of Y02 with CE characteristics per CE characteristics /criteria

Considering "output reduction" characteristics, the 1996-2000 period stands out (Figure 16). This may be linked with the first big impulse of investment in waste management and packaging waste in Portugal. Since the EU Directive 94/62/EC of 1994, setting out recovery and recycling targets for all Member States, Portugal transposed several actions into its legal system[89] with targets extended until the end of 2005 and 2011 (Cruz and Marques, 2014). These developments in the national legislative framework may explain the increased interest in waste recovery and recycling activities identified in the patent data for the 1996-2000 period.

Less applied for are the Y02 patents with the "life cycle extension and reconceptualization" CE characteristic (Figure 16). However, the slightly increasing numbers on the last period (2011-2015) may be related with a growing awareness towards other CE activities, not only linked with the reduction of overall input or limitation/reconfiguration of output, but also a focus on new ways to optimise resources, like reconditioning and remanufacturing options and reconceptualization of products. Moreover, this trend may also be an advanced signal of the reaction to the Commission's Communication *Towards a circular economy: a zero waste programme for Europe*, published in 2014 that anticipated the 2015 *EU Action Plan for the Circular Economy* (EC, 2015a), focusing on the support for a broad CE, from production to consumption, repair and remanufacturing (EC, 2015a).

As mentioned earlier, Y02 patents were categorised as having none, one, or several "CE characteristics". In order to avoid duplication, when a patent falls into more than one criterion, it is weighted accordingly (that is, if it falls on the criteria 1 and 2, it counts 0,5 in each criteria). It seems, nevertheless, also of note to observe how many patents with CE characteristics fall in more than one criterion (especially considering that if we were to follow the narrowest, and more precise, interpretation only patents falling in all three categories could be considered "fully circular") - Figure 17. Overall only 4 of the 260 patents combine the three criteria, with the more usual combinations being "input minimisation" with "output reduction" or "life cycle extension and reconceptualization", thus pointing in the same direction of previous findings: a prominence of energy and regenerative resources input minimisation technologies.

[89] For instance the 1997 Decreto-lei nº 366-A/97 and the 1998 Portaria nº 29-B/98.

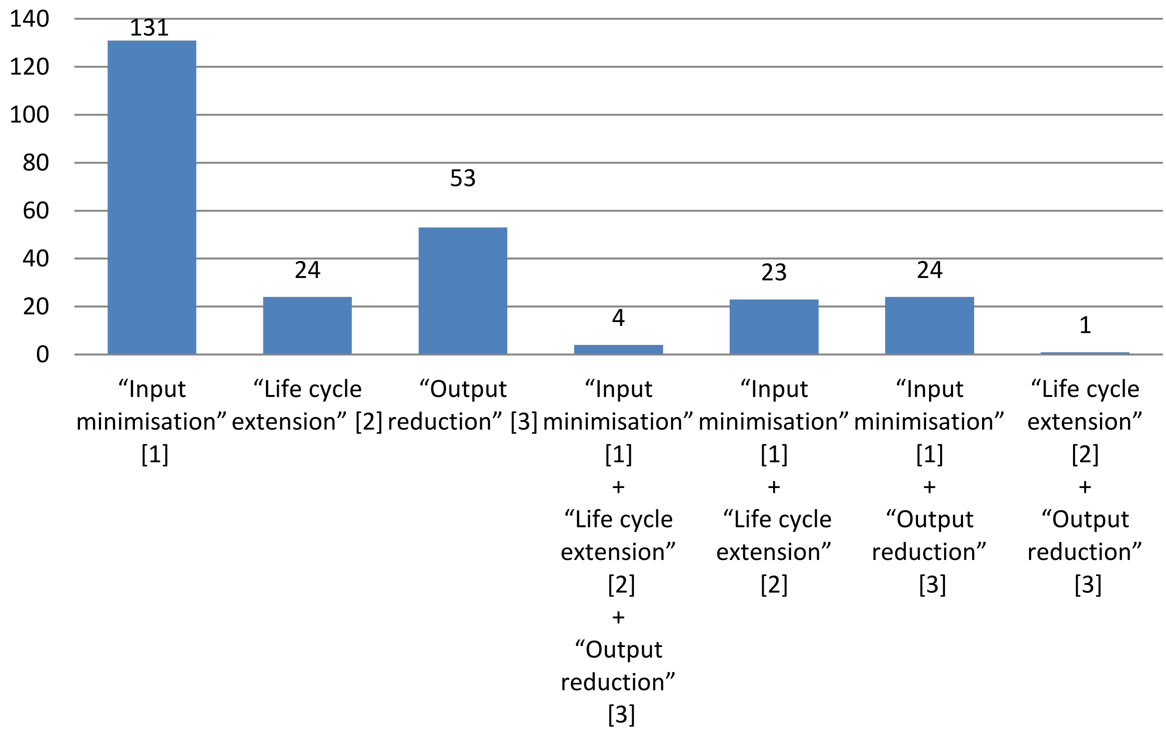

Figure 17 - Overall “pro CE” Y02 per CE characteristics
Note: n=260

6.3.3. Disaggregating the Y02

The disaggregation of the Y02 patents in its sub-categories allowed for some overall considerations regarding EI technological dispersion (Figure 18). In general, the Y02E (regarding energy generation) seems the technology category that captures more interest since 1996, both regarding the global set of Y02 patents, but also the subset of those with CE characteristics (Figure 19). Filings of patents concerning the other Y02 categories seem to be converging, increasing very slowly after 2010.

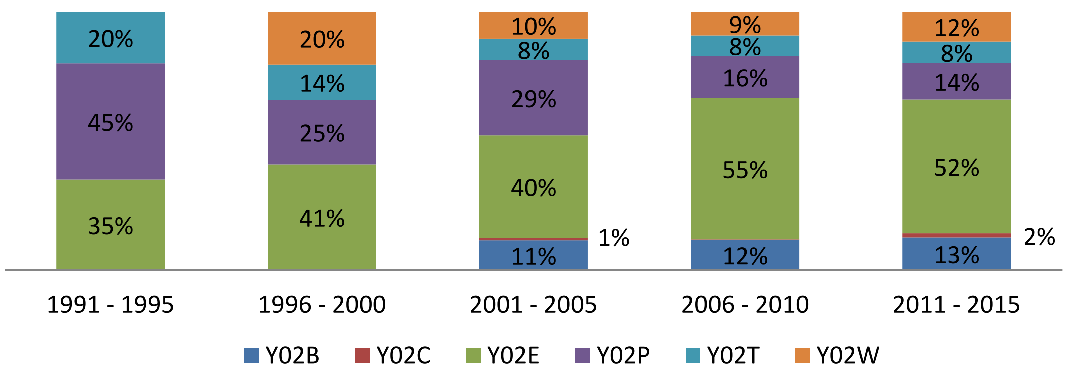

Figure 18 - Overall Y02 % per subclasses

Specifically regarding the Y02 patents with CE characteristics (Figure 19) the focus on patents within the domain of energy generation, transmission or distribution (Y02E) is even more visible, with a clear prevalence over other areas like waste processing (Y02W), transportation of goods and persons (Y02T) and storage/sequestration or disposal of greenhouse gases (Y02C). As mentioned earlier this prevalence of energy generation, transmission or distribution patents may come as a result of the energy policies carried out in Portugal since the mid 1990's.

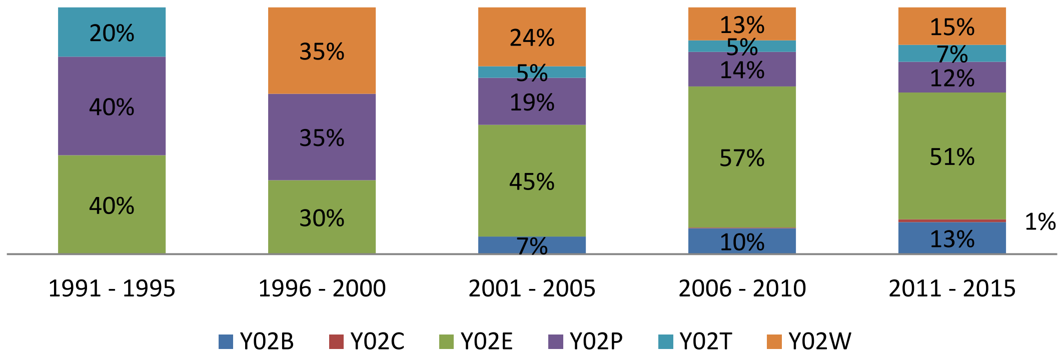

Figure 19 - Y02 patents with CE characteristics disaggregation, per Y02 subclasses

Further focusing the analysis, this time on Y02 patents with CE characteristics, disaggregated per criteria, several trends are made clearer. Considering first the Y02 patents identified with the CE characteristic "input minimisation" (Figure 20) it is interesting to note that after a period of predominance of the Y0E class (similar to the overall results mentioned above), this trend seems to be gradually changing. In the 2011-2015 period, even if Y02E patents still represent 50%, slowly other classes are gaining ground as waste processing (Y02W) and building (Y02B) classes.

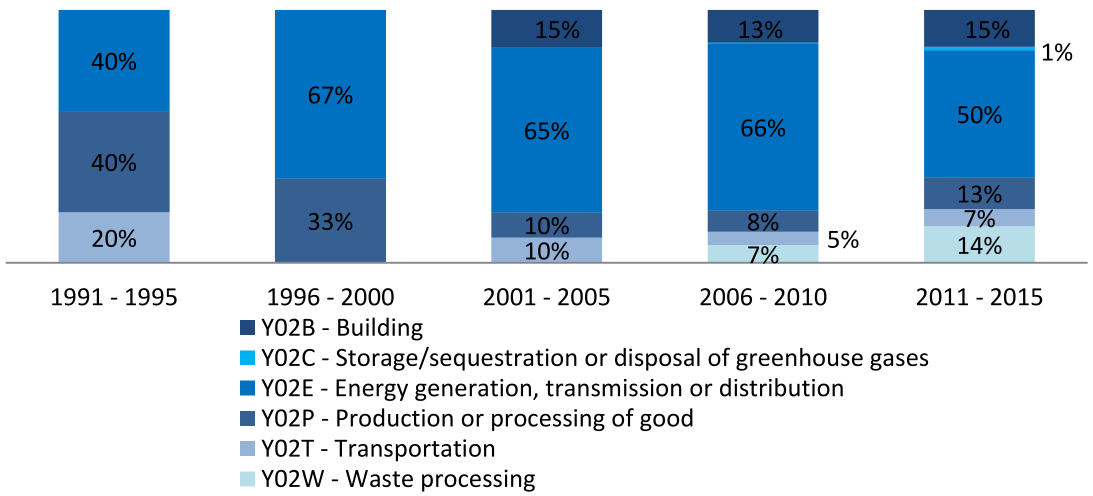

Figure 20 - % of Y02 with "input minimisation" [Criteria 1] CE characteristic per Y02 subclass

A similar evolution can be observed in the case of Y02 patents with the CE "life cycle extension and reconceptualization" characteristic (Figure 21). In the last period (2011-2015) buildings Y02B and energy Y02E have been giving way to other classes, concerning the production or processing of goods (Y02P) and transportation (Y02T). For instance, the latter can be related with initiatives linked with the modernisation of the public transportation network, the development of mobility plans and the promotion of less pollutant vehicles (including electric vehicles and the use of biofuels). As an example of this, the *Green Growth Commitment* (GGC) defines several targets related with mobility and transportation for Portugal (EC, 2017b; MAOTE, 2014).

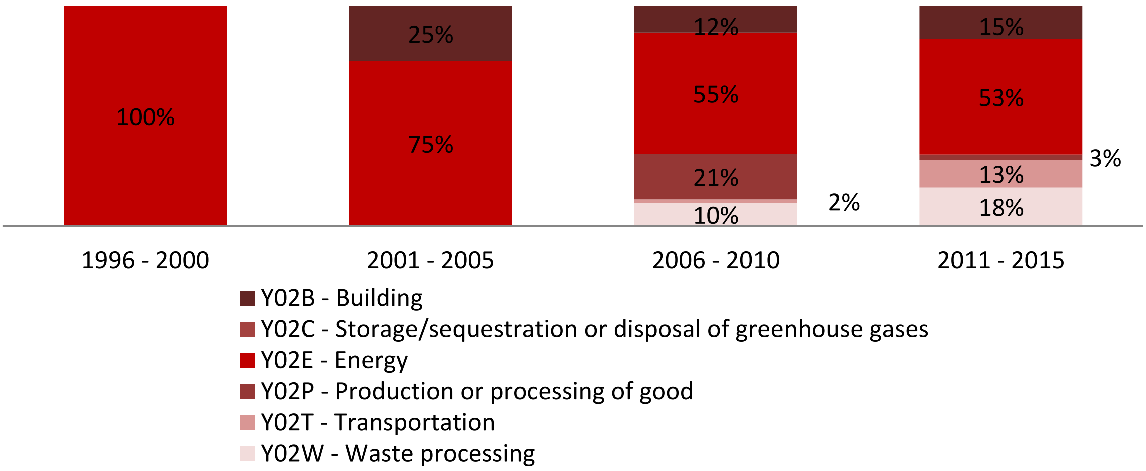

Figure 21 - % of Y02 with "life cycle extension and reconceptualization" [Criteria 2] CE characteristic per Y02 subclass [90]

In contrast with the other trends, Y02 patents with "output reduction" CE characteristic show a comparable dispersion throughout all the periods (Figure 22). Waste processing (Y02W), the production or processing of goods (Y02P) and energy generation (Y02E) classes have maintained a significant importance. This may be linked with the awareness concerning recycling and "closing the loop" activities (Y02W and Y02P), but also with the increased importance of biomass and biofuel options to lessen greenhouse gas emissions and limit the dependence of fossil fuels (Y02E, see for instance Ferreira et al., 2009).

[90] The 1991-1995 period is not showed since no Y02 patents with "life cycle extension and reconceptualization" characteristics were identified.

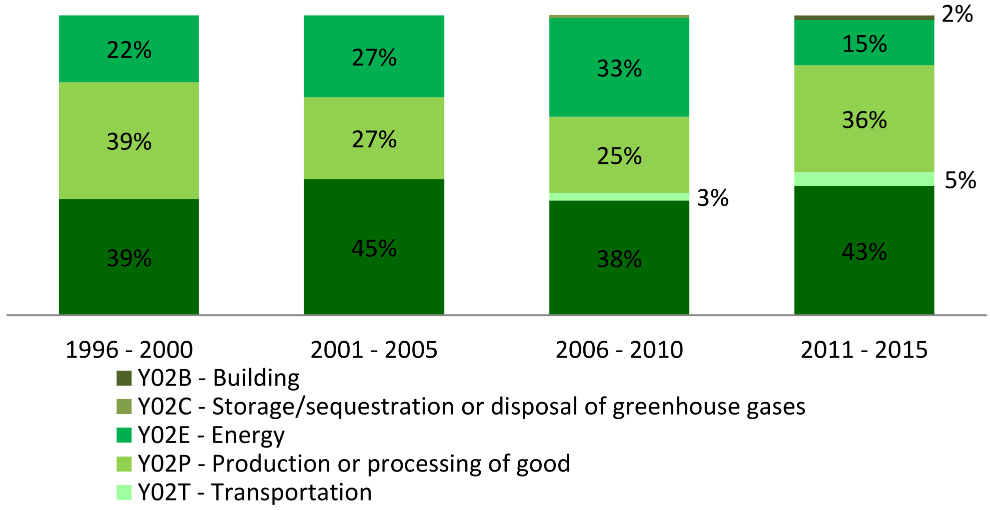

Figure 22 - % of Y02 with "output reduction" [Criteria 3] CE characteristic per Y02 subclass [91]

6.3.4. System actors - Patent applicants

Other feature that makes patents a particularly useful indicator is the information that it contains regarding its applicant - patent owner name, nationality, etc. (Dachs and Pyka, 2010). Regarding patent's applicants a distinction can be made between three major groups: corporate actors; universities or research institutes; and individual inventors. Note that "individuals" are inventors working isolated or in cooperation with other actors, but remaining without revealed business or academic association; "companies" are businesses or other organisations with commercial interests; "universities" include institutions of higher education and/or scientific research.

Up until 2010 "individuals" were the foremost applicants of the Y02 overall patents (Figure 23). Concerning only the Y02 with CE characteristics, the results are similar (even if in the 1996-2000 and in 2011-2015 periods "companies" were the agent that applied most for Y02 with CE characteristics) (Figure 24). These results are not so different from other Portuguese patenting dynamics where individual inventors have been the main type of applicant (Godinho et al., 2007). As this issue has been considered a sign of the fragmented nature of research and entrepreneurship structures in Portugal, it must be underlined, nevertheless, that very few studies exist on the motives of individual inventors for filing patents (Balconi et al., 2004; Conceição, 2003). It should also be considered that these individual applicants may still be linked to

[91] The 1991-1995 period is not showed since no Y02 patents with "output reduction" characteristics were identified

universities, research institutes or to companies, as workers, leaders or even owners. Inventors that are patent holders can for instance use patents to protect their invention and enable the capture of royalty fees (Veer and Jell, 2012).

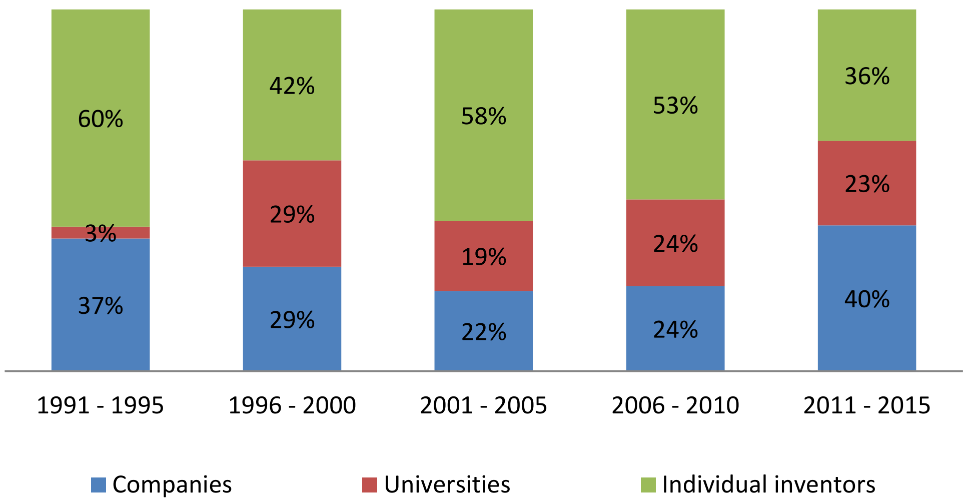

Figure 23 - Overall Y02 patents per applicant type

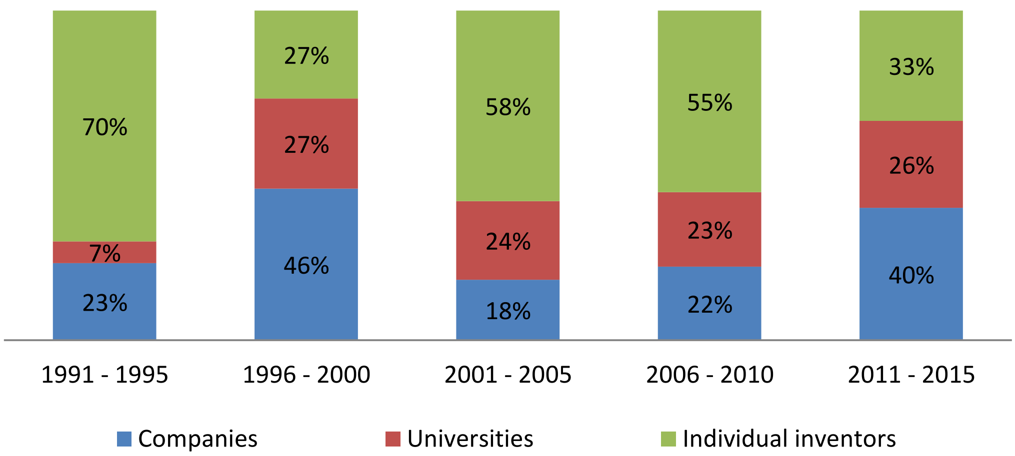

Figure 24 - Y02 with CE characteristics per applicant type

In the last period (2011-2015) "Companies", the key actors in guiding technological trajectories (Partidário and Vergragt, 2000), appear as the most active applicants of Y02 with "CE characteristics". Patents are used by companies to signal to potential investors and/or customers their technological proficiencies and innovativeness (Veer and Jell, 2012), which can be read as an indication of a growing interest among Portuguese companies in strengthening this type of capabilities.

Overall, 62 from the total of 94 Portuguese companies identified have applied for at least one patent with “CE characteristics” (Table 27). [92] Particularly noteworthy are the Portuguese companies which applied to more than one, such as “Ao Sol Energias Renováveis” (renewable energy sector) and “SECIL” (cement manufacturer), with 5 and 4 patents respectively, attesting to the diversity of business interests in this area (Appendix 4).

The percentage of “Universities” as applicants is higher when only considering Y02 patents with CE characteristics (Table 27). Universities’ motives for filing patents may be related not only to an “institutional mission” to shorten the distance between research and the markets, but also with attempts to diminish university dependence on public funds, as patents transform knowledge into tradeable assets that can be sold or licensed-out (Veer and Jell, 2012).

	Companies		**Universities or investigation centres**	
	Total nº of applicants	**Nº of applicants in Y02 patents with CE characteristics**	**Total nº of applicants**	**Nº of applicants in Y02 patents with CE characteristics**
Argentina	0	0	2	2
Switzerland	2	1	0	0
China	1	0	0	0
Germany	5	3	0	0
Denmark	0	0	1	1
Spain	1	1	1	1
Finland	1		0	0
France	6	5	1	1
UK	5	3	1	0
Israel	1	0	0	0
Portugal	95	62	33	27
US	5	3	0	0
Total	122	79	39	32

Table 27 - Nº of Applicant (overall and applicants of Y02 with CE characteristics) Companies and Universities or investigation centres per Nationality

Overall 39 applicants from Universities/Investigation centres were identified, 32 of which applied for Y02 patents with CE characteristics (Appendix 5). There are also some cases of Portuguese Universities/Investigation centres that applied for more than 1 patent (Appendix 6).

[92] Information regarding all Y02 applicant “Companies”, and Y02 with CE characteristics applicant “Companies” in Appendix 3 and Appendix 4.

6.3.5. Networks

Looking into partnerships and networks, only approximately 28% of the overall Y02 were filed in co-application (Table 28). Considering only the Y02 patents with "CE characteristics", a similar number was found, just slightly lower, 27%. Nonetheless, there seems to be an upward trend in later years, especially after 2006 (Table 29 and Table 30).

	Y02 patents	Y02 patents with CE characteristics
Total number of patents in Co-authorship (more than one applicant)	111	70
Total number of patents with only one applicant	290	189
Total	401	260

Table 28 - Patents in co-authorship

The most usual collaborations are between companies and individuals, and between individuals (Table 29 and Table 30). As discussed above, the predominance of individual applicants has to be put in context. It can be a sign of a limited institutional framing in Portugal in these areas, but it is not clear if those individuals are, or not, linked to universities, research institutes or companies. That is, they are often not simply independent applicants, but rather applicants pursuing specific business strategies; as owning a patent may be part of a business plan.

	COM-UNI	COM-IND	UNI-IND	UNI-UNI	COM-COM	IND-IND	COM-UNI-IND
1991 - 1995	1	2	0	0	0	1	0
1996 - 2000	1	1	2	0	0	1	1
2001 - 2005	0	10	0	2	0	4	1
2006 - 2010	4	27	5	2	1	13	1
2011 - 2015	6	8	0	8	1	7	1
Total	12	48	7	12	2	26	4

Table 29 - Number of co-application between actors in the overall Y02 patents
Note: COM - Company; IND – Individual; UNI- University

	COM-UNI	COM-IND	UNI-IND	UNI-UNI	COM-COM	IND-IND	COM-UNI-IND
1991 - 1995	1	1	0	0	0	1	0
1996 - 2000	2	0	1	0	0	0	0
2001 - 2005	0	6	0	0	0	3	0
2006 - 2010	3	18	3	2	1	10	1
2011 - 2015	5	5	0	4	0	2	1
Total	11	30	4	6	1	16	2

Table 30 - Number of co-application between actors in the Y02 patents with CE characteristics
Note: COM - Company; IND – Individual; UNI- University

Regarding co-application among companies, amid universities, and between companies and universities those appear scarce still (30 patents of 401 - around 7% in the overall Y02 patents, and 20 out of 260 - around 8% - in Y02 patents with CE characteristics).

Differently from the overall Y02 patents (where co-applications between universities are more usual), Y02 patents with CE characteristics are more prone to company/university cooperation, increasing since 2006. Several of the 27 Portuguese Universities and Investigation Centres involved in Y02 with CE characteristics patenting efforts have developed partnerships with companies (Appendix 4 and Appendix 6).

It is also interesting to note that in Y02 with CE characteristics, during the 2011-2015 period no co-patents between companies could be found. Perhaps, trust and coordination issues were in play, hampering potential cooperation between companies.

Concerning specific trends regarding Y02 classes, some fields seemed more prone to cooperation. Considering the Y02 with CE characteristics, subclasses mostly linked to energy technologies (Y02E) and processes (Y02P) seem generally more cooperation intensive than others (Figure 25).

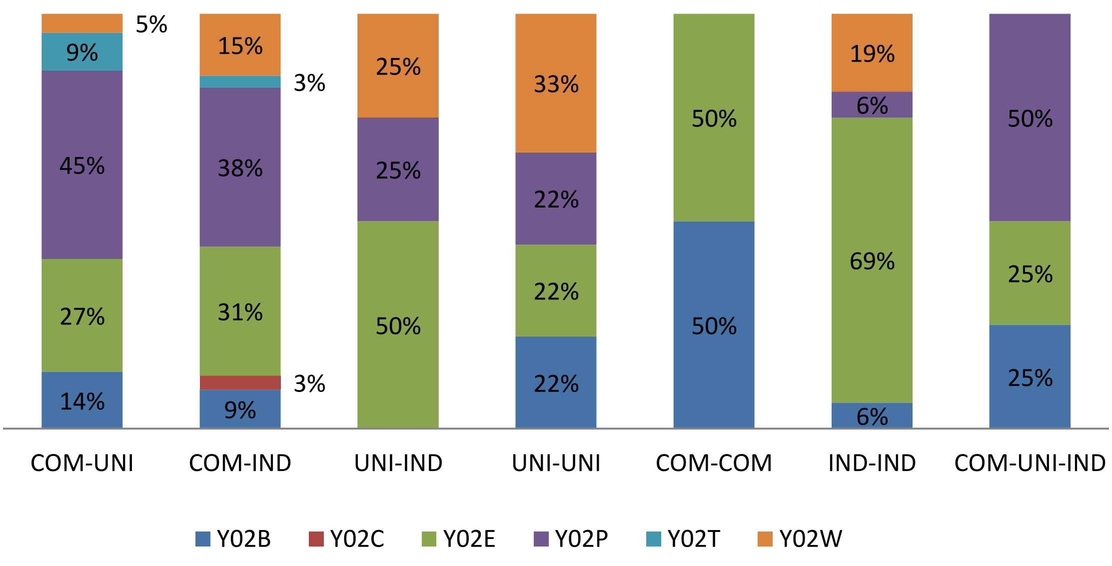

Figure 25 - Percentage of Y02 subclasses of co-applications between actors in the Y02 patents with CE characteristics - 1991-2015.
Note: COM - Company; IND – Individual; UNI- University

6.3.6. Patents as a "circular" innovation proxy, an appraisal of the lessons learned so far

Addressing the innovation metrics agenda from the perspective of "deep sustainability" this chapter tested patent analysis as a pro CE innovation proxy. It probes whether patents can be useful as an indicator of "transformational" techno-economic change, i.e. *CE-inducing EI*. Considering Y02 patent applications by Portuguese innovators, for a period of around 25 years as the basic raw material, a proof-of-concept was purposed. By deriving a framework from the academic literature and by using a participatory approach to validate it, this analysis offered a way to detect, classify and appraise those patents that not only are "green" but also that break new ground toward a new kind of paradigm.

As a proof-of-concept, this new pro-CE technological EI patent-based indicator proposal seems reliable and revealing. It enabled the identification of circular dynamics within the Portuguese innovation system. In Portugal a moderately innovator country developments seem especially intense in the input minimisation and the efficient use of regenerative resources and output reduction areas. The first, especially related to energy production, stressing the important energy policies carried out in Portugal since 2000's. The latter, gaining increasing importance after mid-1990s, coinciding with the big impulse of investment in waste management, waste recovery, recycling activities and packaging waste in Portugal. These findings point to a strategy mainly focused on the opposites sides of the cycle, with a limited awareness to activities related with the optimisation of the use of resources throughout the product life cycle, and the development of repair, reconditioning and remanufacturing options and business models. This, along with the fragmentation in the entrepreneurship structures in Portugal in this area (low number of actors and the predominance of singular inventors), the low number of partnerships and networks (only approximately 27% of Y02 patents with "CE characteristics" were applied in co-applications), may explains the countries' trajectory. Overall this analysis successfully shed light on ongoing trends (that is, signs of effective transformation on the supply-side) and structural issues (systemic failures in terms of actors and networks) that may be valuable for statisticians, innovation intelligence experts and policy-makers.

The limitations of this methodology must nevertheless be discussed. Patents inherent restrictions (patents point to pre-market inventive activity, their economic value is heterogeneous, etc.; see Diaz Arias and van Beers, 2013; Ghisetti and Quatraro, 2013; Griliches, 1990; Lovely and Popp, 2011; Miao and Popp, 2014; Nemet, 2012; Popp et al., 2011) add to the exploitation of the EPO's Y02 class, and the use of a framework derived from the CE literature in order to appraise pro-CE technological EI. To minimise these issues, a triangulation procedure using a participatory approach was used to validate the criteria and codification and increase the validity of the exercise (Bengtsson, 2016). Naturally, further research seems necessary and desirable. The evidence and methodological approach seems only a starting point to further research possibly using econometric and text mining analyses.

This type of analysis enables also the possibility to be extended to comparative studies across countries. It was not pursued here but could be of interest to compare Portugal's performance to both countries that are leader innovators and countries lagging behind, as to understand how those dynamics diverge. This analysis could also help refining the methodology underpinnings. Other ways to further complement this analysis would be to use other detailed quantitative and qualitative information based on examples and illustrative cases (Berchicci, 2008). For instance, one line of further research could be to analyse eco-innovative initiatives with clear circularity focus. To that purpose, looking into organisations' participation on the H2020 call focus area "Industry 2020 in the Circular Economy" (EC, 2016) could deepen the understanding of the characteristics, actors and relations in "circular" EI.

6.4.Main Conclusions

How can CE-friendly technological EI be empirically studied? Yardsticks for assessing progress towards sustainability are needed, especially those that may trace factors and features that have far-reaching impacts upon shared environmental-related goals. Such tools are not only useful to appraise environmental innovation policies helpfulness, but also to identify new business and market opportunities.

The present chapter constitutes an exploratory study, adding to a debate on the potential of the patent indicator for EI assessment and, most especially, in CE research. Notwithstanding the methodological limitations, which invite the need for careful analysis, patents emerge as a workable proxy for innovation and technological achievements towards a CE. The exploitation of the EPO's Y02 class, with the help of a framework derived from the CE literature, can enable the identification and appraisal of pro-CE technological EI.

By taking the Y02 classification scheme as a working bench and Espacenet as a sourcing database, this chapter drew attention to the incidence of CE-oriented inventions of Portuguese origin. It found out that 64% of a sample of “environmental patents” applied for between 1991 and 2015 can be further classified as having circular characteristics.

The recent rise in applications may be related to policy developments in Portugal, even if patterns are somewhat uneven. Many Y02 subtypes seem to have taken-off after the year 2000, most still linked with input minimisation and the efficient use of regenerative resources. As for actors, a predominance of singular inventors is striking, which can indicate a fragmented “circular innovation system” in Portugal. Firms and universities have, nonetheless, become more active over time and the co-application of patents with circular characteristics is increasing (even if slowly) as well. These stylised facts suggest the conclusion that the techno-economic transition is, in the Portuguese case, still rather uneven. Potential implications for the definition of public policies in Portugal would underline the need for investing further in pro-CE policy evaluation exercises and stress the urgency of further synchronising environmental policy and science, technology, innovation and entrepreneurship agendas. Also the collaboration issues and systemic failures in terms of networks must not be forgotten. Within an effort to empirically diagnose the innovation system’s circularity capacities further research is nevertheless needed for the appraisal of non-technological innovation.

CHAPTER 7

ASSESSING "SOFT" PRO-CE EI

Transition is about structural change and is pre-conditioned on the introduction of transformative innovation. However, this type of technically novel, economically useful and industrially actionable knowledge does not need to be radical, technological and manufacturing-based. Tracking and promoting transition thus calls for an expanded portfolio of frameworks and indicators sensitive to incremental, service-oriented, SME-intensive progress towards a circular economy (CE).

Trademarks are the most commonly used intellectual property right (IPR) across the globe (WIPO, 2013). Companies, small or large, of all economic sectors, in high and low income countries alike, use trademarks to commercialise their goods and services (WIPO, 2013). This IPR has been used as a branding solution, to increase the value of assets a company already possess and intends to boost; to signal a new good and service or/and to improve its marketability (Çela, 2015). If successfully associated to a perceived value, a trademark becomes a source of higher margins for the enterprise, increasing its visibility, market reputation and customer loyalty (Greenhalgh and Schautschick, 2013). Being a strategy to positioning a tangible and/or intangible good in the market, trademarks are therefore a sign of a strategic intent, revealing an economic interest in safeguarding an IPR, and therefore have been defined as a proxy of innovation.

Within the agenda on how to appraise "soft" circular innovation, and bearing in mind the importance of social awareness and consumer/user preferences alignment towards CE, trademarks' particular focus on non-technological, marketing and service/goods innovation (Mendonça et al., 2004a) could prove to be an informative proxy, warranting further exploration. To that end this chapter aims to: 1) review the rationale for a softer approach to the socio-techno-economic paradigm-change (section 7.1); 2) summarise the case for trademarks as a meaningful indicator of pro-circular innovation (section 7.2) presenting possible approaches to that analysis (section 7.3); 3) and offering a "proof-of-concept" empirical application of the chosen identified approach (section 7.4).

7.1.Soft innovation for transition

Following Schumpeter, economics started to gradually awake to the phenomena of innovation. After the Second World War and throughout the following decades, innovation policy and metrics went from linear conceptions, structured around the premise of the development of science as the basis of technical progress, to broader frameworks emphasising its “systemic” nature (Fagerberg et al., 2004; Godin, 2017). However, innovation studies have remained, for the most part, focused on those easier to measure science-based or research-intensive activities. Likewise, and for long, this agenda has greatly focused on product-based manufacturing industry while neglecting service innovation, either generated by the service sectors, either by sectors of any other kind (Djellal and Gallouj, 2016; Martin, 2016).

Applied neo-Schumpeterian studies on innovation have consistently pushed forward an empirical agenda that stresses the introduction of new quantitative indicators of economically-useful change. The initial *input* indicator of R&D (OECD, 2008; Patel and Pavitt, 1995) was complemented with an expanding variety of *output* indicators, such as bibliometric data and patent information (Freeman, 1987; Hamdan-Livramento et al., 2016; Haščič and Migotto, 2015; Kim and Lee, 2015; Patel, 2006; Patel and Pavitt, 1995). Only in later years, these *harder* output indicators have been complemented by others of a *softer* kind, such as trademarks and designs (Hamdan-Livramento et al., 2016; Mendonça, 2014; Mendonça et al., 2004a; Schmoch, 2003).

As a splintered phenomenon, change is not only dependent on the availability of technical solutions and financial factors, but also concerned with cultural and organisational artefacts, like symbols and conventions. If technology is an instrumental part of the response (in areas such as clean energy and emissions sequestration), non-technological innovation is no less crucial (including consumer appeal and new business models). The task of tracking transition thus demands a broader assortment of indicators, including those sensitive to non-technological progress. Therefore, this section’s purpose is to scope the opportunities and challenges provided by less conventional indicators, in order to further aid in the mapping, measuring and monitoring of the transition towards a CE.

7.1.1. Soft indicators of innovation

Despite the acknowledgement of non-technological innovation in productivity growth and international competitiveness, particularly in the service industries, the measurement of those dynamics is presently very limited (Livesey and Moultrie, 2008). Even if indicators like design and trademarks were recognised in the 3rd version of the Oslo Manual for their potential to inform policy making in science, technology and innovation areas (OECD, 1992), these proxies have still been scantly used (Livesey and Moultrie, 2008).

7.1.1.1. Design

Design is defined as "the activities aimed at planning and designing procedures, technical specifications and other user and functional characteristics for new products and processes" (OECD, 2005, p. 94). As an IPR, design applications prevent third parties from making or selling a register distinctive or original ornamental or aesthetic aspect of an article, such as a shape, a pattern, or colour. Granted by different jurisdictions, or applied under the *Hague Agreement Concerning the International Deposit of Industrial Designs*[93], these rights can be applied for a broad variety of goods, from packages to textiles, lighting equipment or jewellery (WIPO, 2017a). Design is not limited to aesthetics values, also concerning functionality and ergonomics, being closely connected with companies' differencing efforts. It is a way firms can add value to their goods and services, enhancing their desirability to fit to consumer preferences. Design has even been considered one of the most direct and impactful communication link between organisations and clients, and an active channel between firms innovation activities and the market (Verganti, 2003). As an user-centred activity, bridging the gap between technological and customer-oriented attributes, design has been proposed as an innovation proxy, especially when assessing innovation in marketing and goods and services (Filitz et al., 2015; Tucci and Peters, 2015). Nevertheless, as design encompasses several activities, it is rather difficult to categorise and measure - for instance, in several innovation surveys, only design's more narrow characteristics related with aesthetics, have been "captured" (Galindo-Rueda and Millot, 2015).

[93] System that enables the application of an industrial design in several countries by means of a single application (WIPO, 2017a).

Even if studies using design based indicators are still few, several approaches have already been used. Perks et al. (2005) empirically addressed the role of design in new product development processes using as case studies UK manufacturing companies. Cappetta et al. (2006) proposed and tested a model on how aesthetic and symbolic elements of products and services innovation are adopted. Talke et al.(2009) argued that design ought be considered as a dimension of product innovation, at the same time that Tran (2010) examined the properties of *stylistic innovation*. In turn Filippetti (2011) addressed the role of design as a source of innovation, using a survey covering more than 5,000 European firms, underlining that design and R&D are complementary sources of innovation. Rubera and Droge (2013) explored technology versus design impacts on firm performance, and potential synergies, while Eisenman (2013) theorized the strategic use of design in technological production. In a more conceptual study, Moultrie and Livesey (2014) proposed a framework for measuring design investment using a survey of UK firms. More recently, Filitz et al. (2015) explored firms' rationales behind the use of this legal instrument to protect designs and design innovations.

7.1.1.2. Trademarks

Regarding trademark-based indicators, several considerations must be stressed. The public representation of enterprises' reputation and business has, since the last century, become an undeniable aspect of world-wide contemporary culture with global branding and labelling campaigns (Alcaide-Marzal and Tortajada-Esparza, 2007). Enterprise notoriety and reputation-building efforts have evolved into a sophisticated business tool, warranting enterprises' reputation and, for consumers, the reassurance of quality (confidence that they are getting what they intended to purchase) (WIPO, 2015). As a result, branding strategies have been used as tools for improving market performance and competitiveness (Nguyen et al., 2016). Within marketing studies there is a broad literature addressing these questions (Florea, 2015).

However, despite the usually interchangeable use of trademarks and brands these are different concepts. While a brand includes all that defines the identity of the company and its goods/services, a trademark is also a legal right (WIPO, 2013). Its main functions are to clearly identify and distinguish goods and services of a business and to warrant them protection, by conceding monopoly rights (Gotsch and Hipp, 2014).

In innovation studies, a few empirical works have already used trademarks indicators to analyse innovative activities. Some authors gathered empirical evidence showing that innovative companies are more prone to register trademarks (Çela, 2015; Mendonça et al., 2004a; Schmoch, 2003). Jensen and Webster (2009) surveyed a sample of Australian firms trademarks, correlating those applications with innovation, especially in goods/services and marketing innovation. Greenhalgh and Rogers (2012), using a sample of UK service and manufacturing firms, used trademark counts to monitor product launch. Quite recently, Flikkema et al. (2015, 2014) through a survey to applicants of Benelux Trademarks, underlined the potential of trademarks for innovation policy-making.

Other mechanisms such as certification (also "collective trademarks"), may also be used as ways to assess innovation dynamics. Similarly to IPR trademarks, certification mechanisms as EMAS (Eco-Management and Audit Scheme) and ISO (International Organization for Standardization) are granted after the observance of strict conditions, verified by an impartial party. Certification marks indicate "that the goods and services in connection with which it is used are certified by the proprietor of the mark in respect of origin, material, mode of manufacture of goods or performance of services, quality, accuracy or other characteristics" (IPO, 2014, p. 2). As a practical example, Pekovica and Galia (2009) have applied such indicators when studying quality systems in innovation performance analysis.

7.1.1.3. Designs and trademarks as indicators of transition

Table 31 summarises the main characteristics of design and trademarks indicators, gathering some examples of indicators that have already been used and that underline the potential of those metrics as complementary indicators of innovation. The aim of the following section will be to discuss how such *soft* indicators have been used in the past for analysing innovation dynamics in sustainability studies and what their potential advantages and limitations may be for assessing transformational innovation.

Indicator	Characterisation	Metrics
Trademarks	Reveals marketable non-technological innovation. Can be used according to different perspectives, either more linked to legal rights (trademarks as an IPR); branding (related with branding strategies and labelling), or certification (certification marks, standards). Particularly useful in services, new marketing initiatives, and SME innovation.	- Measures of IPR (trademark registration as a complementary empirical indicator of innovation and industrial dynamics) - Marketing metrics (branding/labelling) - Certification – collective trademarks (e.g. analysis of the impact of International Organization for Standardization "ISO" certification on innovation)
Design	Captures results of design creativity. Points to user-relevant characteristics of novel two-, three-dimensional and digital works. Useful for understanding and following developments in low and high-tech product markets. Enables the gathering of evidence on goods but also services.	- Measures aesthetical creations in the context of dynamic competition - Outputs and inputs information of the Design Sector - Measures of employment on design-intensive professions

Table 31 - Characterisation and examples of indicators application
Note: Inspired on Flikkema et al. (2015, 2014) and Galindo-Rueda and Millot (2015).

7.1.2. Distinctive signs and designs in the context of eco-innovation

Despite the limited used of *soft* innovation indicators these kinds of proxies seem to be receiving increased interest. But how do these indicators fare when applied specifically within sustainability studies? When browsing Scopus database of peer-reviewed literature[94], on the top 5 of the most frequently cited "ecological economics" journals[95], it is possible to glimpse the overall research trends in this field of studies (Table 32).

[94] Scopus database was chosen as this is considered the most comprehensive abstract and citation database, indexing the largest number of peer-reviewed journals (Falagas et al., 2008).
[95] The choice of "ecological economics" to establish the boundaries of the research was influenced by two factors, one of a theoretical nature, and one considering practical application. First, ecological economics has been pointed out as a valid theoretical framework from which CE could draw guidance and support (Korhonen et al., 2018a). Secondly, this definition profited from a recent update on influential publications in ecological economics (Costanza et al., 2016). Scopus search was done in the Title, Abstract and Keywords, up until 2017 (31.12.2017), by "soft" innovation descriptors (as addressed in section 7.1.1) regarding trademarks (and several related marketing/certification descriptors) and design.

Focus and Searched Descriptors	Trademarks Indicators			Design Indicators
	Intellectual Property Rights: *Trademark** [96] **OR** *Trade-mark*	**Marketing:** *Brand** **OR** *Label**	**Certification (Collective Trademarks):** *ISO 1400** **OR** *EMAS*	**Design registrations:** *Design* **AND** *innovation* [97]
Top Journals				
1. Ecological Economics	0	60	9	15
2. Ecological Indicators	0	24	3	2
3. Journal of Cleaner Production	1	159	135	143
4. Sustainability	0	12	0	8
5. Energy Policy	3	120	1	49
Total N of articles	4	375	148	271

Table 32 - Number of articles identified in Scopus, per descriptor, in top 5 of the most frequently citing "ecological economics" journals

Potential advantages and limitations of the discussed indicators are summarised and compiled in Table 33. Examples and characteristics do not intend, however, to be exhaustive, but rather to organise evidence of the most relevant features. Overall it seems that soft indicators have yet to be substantially used in the specific field of ecological economics, and even more in CE approaches. Design metrics, for instance, fail to take advantage of available industrial design databases such as Designview. Generally, publications focus on eco-design in the improvement of products (Clark et al., 2009) or "strategic design for sustainability" in product service systems (Manzini and Vezzoli, 2003).

As for marketing, the importance of "branding activities" as a way to ensure companies the appropriability of green investments has been acknowledged (Kumar and Christodoulopoulou, 2014); the same been said regarding eco-brands in the development of markets for sustainability certified products (Chkanikova and Lehner, 2015); as well as ecolabels' role in the improvement of the image and sales of "environmentally" sound products (Dangelico and Vocalelli, 2017).

[96] The asterisk was used to retrieve all words with a given stem.

[97] Search by the descriptor "design" originated 2725 results. As this was a large number of articles it could indicate a bias in the search, therefore a new filter was added to the search: "innovation" as innovation indicators were the main focus of the research.

		Potential advantages	Potential limitations
Trademarks	**Intellectual Property Right** None detected	Identified as a complementary indicator in innovation studies especially in low-tech industries, goods/ services and marketing innovation (may be applied to CE and sustainability transition) Availability of Trademarks databases (that compile data on applicants and categories of new trademarks) Can be used to gather information closer to the market (reveal an economic interest in safeguarding a property right)	Limited information on market success Methodological difficulties in assessing trademarks circularity (identification limitation) Difficult to assess economic return of trademarks investment
Trademarks	**Marketing (Brands/Labels)** Survey to reveal consumer preferences for ethical and environmentally sound labelling (Loureiro and Lotade, 2005) Analyses the role of retail eco-brands in the development of markets for sustainability certified products. (Chkanikova and Lehner, 2015)	May be of use to assess dynamics in marketing innovation Particularly interesting in consumer awareness and acceptability to "green" products and services Can be used as an indicator of sustainable market development.	Limitations regarding representativeness and generalisation (survey use)
Trademarks	**Certification (ISO / EMAS)** Uses a set of German EMAS-validated facilities to study effects of EMAS on technical environmental innovations and economic performance (Rennings et al., 2006) Sample of 8797 EU SME's used to explore whether firms adopt Environmental Management System and green patents as complements or substitutes (Corrocher and Solito, 2015) Analysis of the new standard "BS 8001:2017 – Framework for implementing the principles of the circular economy in organizations" recently launched by the British Standards Institution (Pauliuk, 2018)	Enables the gathering of data at the company level and comparison between enterprises (benchmarking) Especially interesting in SME's as those enterprises tend to favour environmental certifications rather than patents Enable the comparison of environmental performance over time.	Often considered as organisational innovation indicators – focused on implementation of management practices (limitations when studying marketing and goods/service innovation). Deriving CE indicators from this data is difficult
Design	**Intellectual Property Right** None detected	Potential complementary indicator in goods/ services innovation (key activity in the preparation of product innovations Availability of design application databases (compiled, available data) May point to organisation or business capabilities	Methodological difficulties in assessing design circularity (identification limitation) Difficult to assess economic return of design investment
Design	**Product/system design** Case studies analysis. Discuss how eco-design could include economic and social concerns. Focus on sustainable improvements to products by applying elements of life cycle thinking (Clark et al., 2009) Theoretical contribution on the use of design for sustainability (Gaziulusoy and Brezet, 2015). Promotion of the concept of 'strategic design for sustainability' in product service systems using case studies analysis (Manzini and Vezzoli, 2003)	Potential to gather information on goods/services, process and marketing innovation	Limitations regarding generalisation and external validity Do not enable information on the market dynamics or acceptability Difficult to assess economic return of design investment

Table 33 - Advantages and limitations of "soft" indicators.

Other mechanisms like environmental certifications, i.e. environmental management systems and ecolabels, have been recognised by their relevance in the transition towards a CE. In Europe, for example, a report concluded that voluntary mechanisms as the EU Ecolabel Scheme and the Eco-Management and Audit Scheme (EMAS) are important in a CE, but underexploited, needing to be made more effective to really have an impact (for instance in the interface between products and chemicals and in requirements such as re-manufacturing) (EC, 2017d, 2017e).

Trademarks as IPR constitute a clear gap of knowledge in this field. Regarding the only 4 articles identified, two mention "trademarks" because of the use of patent data identified from the United States Patent and Trademark Office (Lee and Sohn, 2014), while the other two use "trademarks" as an expression and not as an IPR (Weiss, 2017). To the extent of our knowledge, not a single publication uses trademark data to assess and monitor innovation progress in ecological economic studies and as an innovation complementary indicator to assess transition towards a CE. But why is that? Can trademarks be reconfigured to assess EI in CE transition?

7.2.Deploying soft innovation indicators: Trademarks

If not more, EI goods and services in a CE can be expected to have at least the same problems regarding differentiation and recognition: "The choices made by millions of consumers can support or hamper the circular economy. These choices are shaped by the information to which consumers have access, the range and prices of existing products, and the regulatory framework" (EC, 2015a, p. 6). It is not enough that products and services themselves are available, or "better", consumers have to be aware of their existence and be swayed to try them out (or pay more for them). One should therefore expect that agents "aware" and implementing CE considerations also use this IPR, as it would seem of similar importance for marketing to underline CE differentiation, especially if there is already an investment in R&D (for instance a patent) (Gupta et al., 2013). Enterprises may patent environmental technological invention, but they may also trademark the intangible part of that invention (Flikkema et al., 2015). Trademarks analysis may be helpful in assessing said dynamics and is a search avenue that has not been genuinely pursued as of yet. Being closer to market than design, this indicator seem to have the largest potential for CE monitoring, potentially revelling marketable non-technological advances and enabling gathering information on goods and services and marketing innovation (as Table 33 stressed).

Within the traditional innovation indicators, this output proxy combines advantages regarding detail and time series that justify its use. It seems also an advantage to be able to combine trademark data (more focused on market introduction) to previously identified information on patents (first innovative step of a more technologic focus) as a way to better grasp innovation system dynamics (Flikkema et al., 2015). Despite the inherent methodological difficulties (that will be discussed in sub-section 7.2.3) this indicator was considered to be of value to managers, researchers and policy-makers concerned with CE's implementation.

7.2.1. What is a trademark? Why to trademark?

A trademark is a sign, or sets of signs, that can be represented, graphically (words, drawings, letters, numbers) or by other means as sounds, the form of the product, or even its packaging (Table 34) (WIPO, 2006). A trademark legally protects the aspects of a company's identity that are unique and specific (Gotsch and Hipp, 2014). If granted, a trademark is, like patents or copyrights, an IPR, warranting exclusive rights and preventing third parties from using, producing, making, selling or economically exploiting, without consent, an identical or similar sign in identical or similar goods or services (Schautschick and Greenhalgh, 2016).

Type of Trademark	Description
Combined	Combines both words and figures
Figurative	Graphical representation (whether or not including words and/or colours)
Word	Consist solely of words (letters, numbers, combination of letters, numbers and words) containing no figurative elements
Other	Any trademark type apart from those already covered by Figurative and Word, namely colours or combinations of colours; three-dimensional marks; sound marks.

Table 34 - Types of Trademarks
Note: Inspired on IPR (2012) and WIPO (2006).

It was the *Paris Convention* of 1883 that established rights and protection to registered trademarks. This convention was later reinforced, in 1891, at the *Madrid Agreement Concerning the International Registration of Trademarks*. Empirically, trademarks have the advantage to be broken down and classified by a set of specific criteria. The Nice Agreement of 1957 establishes an international classification for the purposes of trademark registration - the Nice Classification - concerning goods (classes 1 – 34) and services (classes 35 – 45) (IPR, 2012; WIPO, 2017b). Nowadays, a trademark may be registered in national, regional, or international trademark offices. An organisation may choose to apply to one or several countries' protection (international application does not create a "world" or "international" trademark, but a bundle of national rights). The World Intellectual Property Organization – WIPO, as the global coordinating institution can, for instance, extend the protection to up to 70 countries (the signatory countries of the 'Madrid Agreement'). In Europe, the European Union Intellectual Property Office -EUIPO (until March 2016 named Office for Harmonization in the Internal Market - OHIM) enables a single application to all Member States coverage in a EU trademark - EUTM (previously named Community Trade Mark - CTM) (EUIPO, 2017; TMview, 2017).

Several factors, related with protection, marketing and financial motives lead to companies' strategic use of trademarks as IPR. Especially in services, where other forms of IPR (as patents) are less available, a trademark represents the opportunity to protect innovator's first-mover advantages. Considering expected benefits, as increased customer loyalty and heightened marketing success, a trademark is one of the company's most valuable assets and its protection vital (Block et al., 2015).

Marketing motivations are also very important. While patents increase the perception of the company's technological image, a trademark signals its differentiation strategy (Block et al., 2015), it is a doorway into a new product/service segment, or a new market (Aaker, 2007; Gotsch and Hipp, 2014; Mendonça et al., 2004a). Marketing motivations are linked with a company's need to increase its visibility and to differentiate from competition, involving considerations regarding quality assurance, consumer loyalty, and premium pricing (Schautschick and Greenhalgh, 2016).

This signalling function is also closely associated with financial motives to trademark as, in one hand, it generates investment incentives for companies to keep improving their products and, simultaneously, attracts investors or licensees (Block et al., 2015; Schautschick and Greenhalgh, 2016). The motivations to trademark are varied, but dependent on several factors, like company size, sector and even country (Block et al., 2015). Still, as the materialisation of a strategy to position new goods and services in the market, "Trademark data" has been seen as partial indicator of innovative activity, as it will be discussed in next section (Gotsch and Hipp, 2014; Mendonça et al., 2004a; Millot, 2009).

7.2.2. Trademarks as innovation proxy

Since the seminal paper of Mendonça et al (2004a), trademark-based indicators have been increasingly used in innovation studies (Çela, 2015; Davis, 2006; Gotsch and Hipp, 2014; Mendonça, 2014; Millot, 2009), innovation rankings (such as the Innovation Union Scoreboard - see EC, 2017f), and policy reports (Millot, 2009).

Starting in the early 2000s, several empirical studies (Table 35) have further used trademarks counts to show a positive correlation with innovative activities (Greenhalgh and Rogers, 2012; Jensen and Webster, 2009). This indicator has been considered of special interest in capturing small and medium-sized enterprises innovation efforts (considering the lower cost, SMEs are more prone to use trademarks as IPR, see Rogers et al., 2007). Other studies have used case-level approach (focused on studying the characteristics of individual trademarks) combining information on trademark registrations and new products announcements, as to enable a deeper study on how individual product innovations are protected by a trademark (Malmberg, 2005), or to investigate motives behind the registration of trademarks and innovative activity (Flikkema et al., 2015, 2014).

Notwithstanding the limitations that trademark proxies imply, regarding its use and interpretation, this is thus far an under-exploited source of information that could be used as an additional indicator in fields where measurement is inherently difficult (Schautschick and Greenhalgh, 2016). As standing indicators of innovation fail in some measure to capture marketing and organisational innovation (Flikkema et al., 2014), trademarks can be a complement in the assessment of lesser known patterns of a "softer side of innovation" linked with market introduction and bridging the gap between supply and demand (Gotsch and Hipp, 2014; Mendonça, 2014; Millot, 2009). Notably, this proxy holds potential in non-technological innovation sectors where traditional data sources like R&D or patents are less effective measures of innovation.

Reference	Methodology	Focus	Coverage	Data
Mendonça et al. (2004a)	Number of trademarks	Trademarks as a complementary empirical indicator of innovation and industrial dynamics	Nation aggregated data (EU 15 countries)	CTM's obtained from OHIM (the Organisation for the Harmonization of the Internal Market)
Griffiths et al. (2005)	Number of trademarks	Proxy for intangible capital	Sample of Australian firms	IBIS World's information database
Malmberg (2005)	Number of trademarks	Trademark registration is correlated to innovation activities of firms	Major Swedish engineering companies as well as the entire Swedish pharmaceutical industry	Swedish patent office
Rogers et al. (2007)	Number of trademarks	Investigate whether applications for trademarks are suggestive of product innovation	Data on around 1,600 large UK firms	Oxford Intellectual Property Research Centre database
Jensen and Webster (2009)	Survey	Trademark applications are correlated with innovation, especially product and marketing innovation	Sample of Australian firms	IBIS World's information database
Greenhalgh and Rogers (2012)	Number of trademarks	Monitor product launch by using trademarks, patents and research and development	UK service and manufacturing firms 1,600 large UK firms	Oxford Intellectual Property Research Centre
Mendonça (2014)	Number of granted trademark rights	Trademarks as a complement to indicators such as patents, pointing to the softer side of innovation	Nation aggregated data (28 EU member states)	CTM's obtained from OHIM
Gotsch and Hipp (2014)	Survey	Trademarks as a way to protect innovation and intellectual property	278 knowledge-intensive German businesses	Sample of Knowledge-intensive business services industries in Germany provided by Bureau van Dijk and the Credit Reform Association.
Flikkema et al. (2014)	Survey	Value of trademarks for innovation studies and policy-making	660 new Benelux trademarks	Trademark Innovation Survey
Flikkema et al. (2015)	Survey	Trademarks as an innovation indicator and the potential of matching trademark data with patent data in innovation studies	1015 applicants who have applied for a Benelux Trademarks n=456; or CTM n=559.	Trademark Innovation Survey 2 (databases of the respective trademark offices Benelux Office for Intellectual Property; OHIM; TMview)

Table 35 - Example of studies exploring the relationship between trademarks and innovation activity.
Note: Inspired on Flikkema et al. (2015) .

7.2.3. Research possibilities and challenges

Methodologically, trademarks have to be used with caution. Trademark-based indicators are relatively new and experimental in innovation studies (Mendonça et al., 2004a). Trademark value is heterogeneous and a new trademark does not automatically means a new innovation (Aaker, 2007). They are not equally informative: the propensity to "trademark" varies between sectors, and international comparability is difficult (Schautschick and Greenhalgh, 2016). Furthermore, as a trademark can be registered in several Nice classes, the number of counts in all classes can be higher than the real total number of trademarks (Mendonça et al., 2004a). These are all reminders that have to be accounted for, to avoid misrepresenting the data when using this indicator.

In the specific subset of environmental innovation, one other major limitation in using trademark-based indicators is the difficulty to identify a subset of "environmental related" trademarks. Contrary to patents, where several classification schemes already exist (like the Y02 class, the "green inventory", or the OECD "green patents"), trademarks' Nice classes do not allow an easily operationalisation of "green" or EI trademarks. Therefore, several strategies were considered, and preliminarily tested, to determine the best approach in order to identify pro-CE trademarks (Table 36).

Potential trademark identification approach	Advantages	Disadvantages
Search trademarks by "circular economy" descriptors in several languages [98]	Exemplifies global trademarks trends linked to CE	-Very limited analysis (several "circular" brands do not have to have "circular economy" in its brand name) -After cleaning the data (remove duplicates and trademarks not connected to CE, e.g. "Circular": a trademark of a brand of a circular fan) there are only 46 trademarks (small sample) -Lack of trademarks registered by Portuguese or in Portugal with these descriptors (it hampers the study of hard and soft pro-CE innovation in the Portuguese innovation system).
Search trademark filed by previously identified actors with "circular patents"	Enables the identification of a sample of trademarks from institutions aware and sensitive to CE efforts. Enables the study of "soft" innovation trends and dynamics	-Identifying agents using patent data ("hard" technological innovation proxy) may skew the trademark analysis towards technology, and underestimate more non-technological areas. -It is difficult to correlate a trademark (or trademarks) to a specific patent -Very time consuming (manual process)
Search trademark filed by recognised CE agents, i.e. renowned enterprises and other actors engaged in CE efforts. For instance, EMF CE100[99]; the World Economic Forum's "The Circulars" awards; or in the case of Portugal, actors identified in the examples made available by the government's CE portal Eco.nomia[100].	Enables the identification of a sample of trademarks from institutions aware and sensitive to CE efforts. Enables the study of "soft" innovation trends and dynamics	-Examples of enterprises and goods and services already identified as "circular" (inclusion and exclusion criteria not known) -Not all the actors are involved in innovation and have trademarks -Very time-consuming process (manual).

Table 36 - Three possible CE trademark identification strategies

[98] ("Circular economy"; "Économie circulaire"; "Economía Circular"; "Circulair "; "Kreislaufwirtschaft"; "Economia Circolare"; Cirkulær; 循环经济; .(огещудуб акимонокэ ;الاقـتصاد الدائري

[99] The Circular Economy 100 brings together several actors (corporates, governments and cities, academic institutions, emerging innovators and affiliates) in a programme focused on building capacities and networks towards a circular economy (EMF, 2014b).

[100] Eco.nomia is a platform, launched in 2016, promoted by the Portuguese Ministry of Environment that intends to divulge the advantages and opportunities of the CE. It makes available a set of "circular examples" of Portuguese actors (Government of Portugal- Ministry of Environment, 2017b).

Searching trademark databases for “circular economy” synonyms in several languages[101], as “brand name”, could be interesting to get a glimpse of overall trademark dynamics. It fails, however, to be inclusive. The most obvious limitation is that several trademarks may not specifically have “circular economy” in its name, therefore excluding a broad set of data (only 46 trademarks were identified - see Table 37). As such, this method can be considered as a complement, but has to be aided with other approaches.

	TMview	Global Brand Database	Total included
“Circular economy”	21	11	23
“Économie circulaire”	8	0	8
“Economía Circular” “Economia circular”	1	1	1
“Circulair ”	14	22	4
“Kreislaufwirtschaft”	5	5	4
“Economia circolare”	5	0	5
Cirkulær	1	1	1
循环经济	3		0
الدائري الاقتصاد	0	0	0
экономика будущего	0	0	0

Table 37 - Search in Global Brand Database and TMview database for trademarks with “circular economy” descriptor in eleven languages

Another possible approach could be to use a list of institutions (companies/ associations/etc.) identified in patenting efforts in CE areas, and study its trademarks dynamics. However, considering that patents are a “hard” innovation proxy, this approach could include bias, since results could be skewed towards more technological sectors.

The identification of CE aware and engaged institutions on already available lists was found to be the most comprehensive approach. The search for those “trademark applicants” enables the study of trends on “soft” innovation dynamics of actively engaged and involved actors, with an already existent CE agenda. Initiatives like the “Circular Economy 100” of the EMF[102] or the World Economic Forum’s “The

[101] The “circular economy” synonyms in the eleven languages were gathered from the EMF institutional site.

[102] A CE programme focused on build capacities and networks that lists several identified actors (corporates, governments and cities, academic institutions, emerging innovators and affiliates) (EMF, 2014b).

Circulars"[103] could provide interesting lists of CE aware "actors". This approach has, as its main advantage, the independent (and impartial) identification of CE "agents". Also, there is no reason to believe it to be skewed towards technological sectors.

7.3.Methodological considerations

The establishment of the usefulness of trademarks as a partial proxy of innovation is a step towards the identification of non-technological, "soft" pro CE EI indicators. Table 38 synthesises the research steps regarding methodological aspects, data collection and analysis.

AIM	How to access "Soft" EI "circularity"?
DATA ID	▪ Trademarks as an EI Indicator ▪ Use of CE renowned actors to identify their trademark dynamics
DATA COLLECTION	▪ Search in TMview and WIPO Global Brand databases ▪ Trademarks from actors ID in the CE Portuguese Portal Eco.nomia ▪ After data cleaning - 104 trademarks from 34 different applicants
DATA ANALYSIS	▪ EI evolution (How many trademarks per year) ▪ EI market dispersion (trademarks per Nice classification) ▪ Actor identification (Which are the main organisations?) ▪ Cooperation between agents (partnerships between organisations)

Table 38 - Research steps

The empirical application of the approach previously detailed in 7.2.3 section was carried out using data collected from TMview and WIPO Global Brand databases. Those are two of the most recognised trademarks databases giving access to a wide-ranging number of trademark applications and registrations. As both platforms have been reinforcing their cooperation, nowadays it is possible to do searches simultaneously in both databases (IPR, 2012).

As for the list of "actors", the search was based on the information gathered in the "Examples" of the "Eco.nomia" web platform. This is a CE repository of knowledge and networking promoted by the Portuguese Ministry of Environment, where several

[103] This is a annual initiative of the World Economic Forum and the Forum of Young Global Leaders that recognises organisations making notable contributions to the CE (The Circulars, 2017).

examples of public agents, companies and other institutions engaged in CE can already be found (Government of Portugal- Ministry of Environment, 2017b). Considering the previous use of the patents indicator on the analysis of “hard” CE, using Portugal as case study, the same example was considered an advantage to enable further conclusions. The Portuguese case is a curious international example as this is a country subject to high economic pressures with an innovation policy oriented to “catch up” to the EU political agenda. Regarding CE, the country is now defining its national strategy (Government of Portugal- Ministry of Environment, 2016). As a result, this is an example of a small country in a globalised world, needing to relaunch its economic competitiveness, at the same time redirecting its system towards “circular” practices.

The 76 Portuguese examples presented in the Eco.nomia portal[104] were thus used in the trademark search (Figure 26). Queries were performed in the TMview and Global Brand Database by “Trademark applicant” and “Trademark name”, depending on the information provided in the example. For instance, and especially concerning start-ups, searching by applicant sometimes did not return any results as the trademark was filed by an individual actor. To avoid false negatives the search was also conducted in the “Trademark name” option. As to prevent false positives, whenever the search by applicant produced a large number of trademarks (> 20) those results were filtered, checking if the identified good/service in Eco.nomia was within those results. If not, in order to limit "noise" within the sample, those cases were rejected (Table 39).

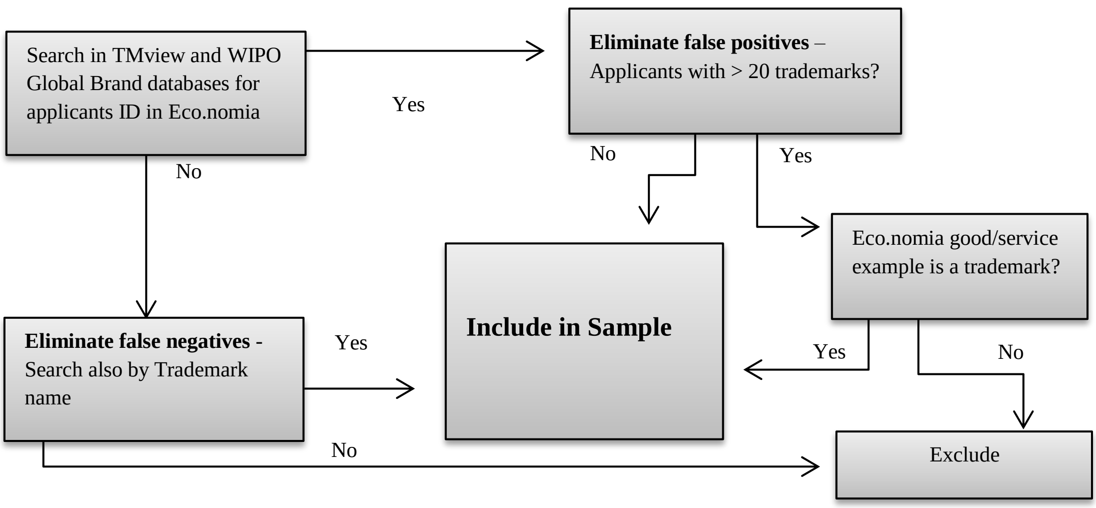

Figure 26 - Trademark identification process

[104] Last search, performed in 20.09.2017

Companies	Nº of trademarks
EDP	566
CTT	152
Sonae	88
PT	66
Sociedade Ponto Verde	58
Corticeira Amorim	44
Revigrés	32
Soguima	22

Table 39 - Trademarks left out

Overall, between 2003 and 2017[105], 104 trademarks, from 34 different applicants, were identified. The data collected comprises information regarding name of applicant, date, type of mark (word, figurative, combined), and Nice class (Appendix 7). Similarly to what was done regarding patents (chapter 6), the structural components of a national innovation system, concerning contextual trends, actors performance and dynamics, were used as a "focusing device" for examining the trademarks' empirical information. Next section explores the resulting findings.

7.4. Soft "pro Circular Economy" eco-innovation: What do trademarks tell?

7.4.1. Exploring the structure and the dynamics of the Portuguese "circular" trademarks landscape

Some basic observations on Portuguese trademark dynamics for CE aware actors can be made. In 14 years, 104 trademarks were applied by 34 different applicants corresponding to an average of about 7.4 trademarks a year. Total applications appear to be growing over time (from an average of 5 trademarks in 2003-2007 to 9.2 in the 2013-2017 period) nonetheless with fluctuations (Figure 27). These oscillations may be associated with variations in economic activity (in line with general trademark dynamics - see for instance Mendonça, 2014). For instance, the initial upward trend that was interrupted in 2010 may be related with the impact of the global financial crisis on Portugal and the 'Troika' bailout of 2011 (as it is also visible in patent indicators). But the following upward trend since 2014 may also be connected with an increasing CE

[105] Last search, performed in 25.09.2017.

awareness promoted by uptakes on the subject by several institutions (in 2012 the EMF launched the first of three economy reports on the potential for significant benefits across the EU of the transition to a CE - see EMF, 2012). The European Commission's Communication *Towards a circular economy: a zero waste programme for Europe* of 2014, and the 2015 *EU Action Plan for the Circular Economy* (EC, 2015a) may have also operated a greater awareness to CE issues (EC, 2015a).

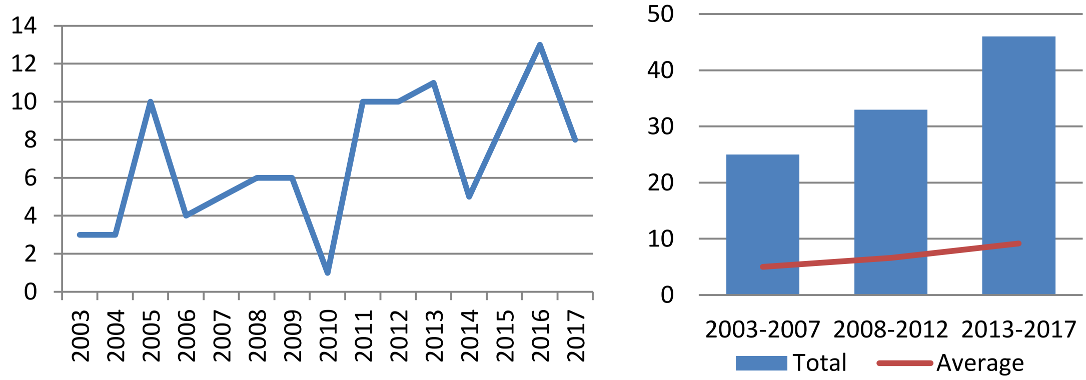

Figure 27 - Trademark applications, 2003–2017[106]
Note: Elaborations on the trademark corpus; applies to all tables and figures in the chapter from now on, unless otherwise stated.

7.4.2. Disaggregating Goods and Services trends

In terms of category breakdown, the top ten most trademarked classes received around 59.2% of all requested classes and the trademarked classes are divided more or less equally between services and goods - 5 classes each (Table 40). Despite services increase in importance, especially after 2015 (Figure 28), in overall goods are still the main trademark classes.

Rank	Class	Type	Nº Applications	% of total
1	19 - Building materials	Goods	11	11%
2	25 - Clothing and footwear	Goods	9	9%
3	35 - Advertising and business management	Services	8	8%
4	42 - Research and other services	Services	7	7%
5	41 - Education	Services	5	5%
6	24 - Textiles and substitutes for textiles	Goods	5	5%
7	37 - Building and construction	Services	4	4%
8	40 - Services not included in other classes	Services	4	4%
9	28 - Games, toys and playthings	Goods	4	4%
10	21 - Household or kitchen utensils	Goods	4	4%
Total			61	59%

Table 40 - Most "trademarked" Nice classes – Top 10

[106] 2017 until last search 20.09.2017.

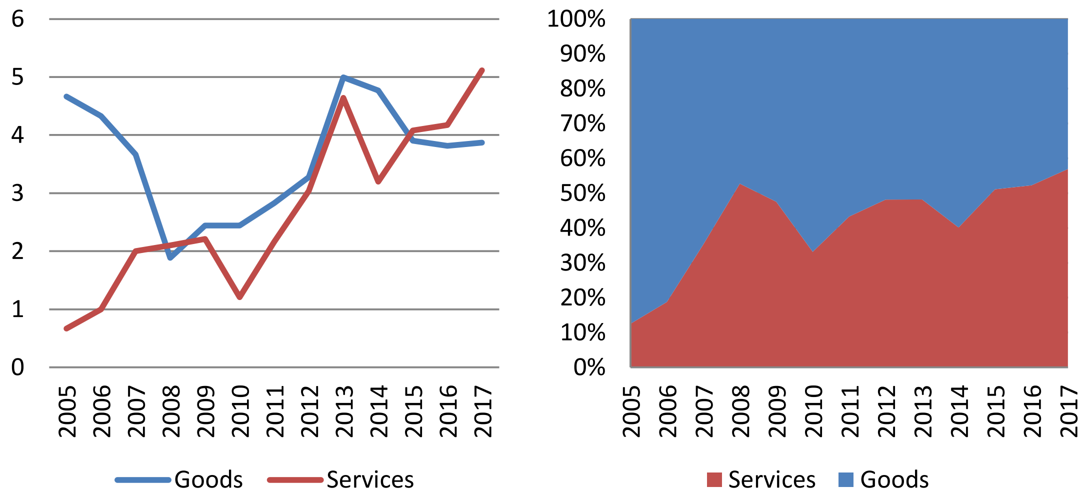

Figure 28 - Sectoral dynamics of trademarks (total and %)

Heterogeneity in trademarks applications in goods is evident in terms of distribution, with the most sought after product categories being: building materials (Class 19), and clothing and footwear business (Class 25). These findings seem in tune with the sectoral identification of priorities within a CE that have stressed the opportunities for these sectors. In the case of clothing industry, as it currently operates mainly on a linear consumption model (limited useful life and large share of waste ending in landfills), it has the potential to develop new profitable businesses (reuse and cascading of clothing) and to significantly reduce the use of virgin materials (EMF, 2013). As for construction, this sector has been recognised as having further potential for closing regional and local loops (Leising et al., 2018; Mahpour, 2018) and there are already several measures that may explain this prevalence in the trademarks. For instance, the EU Waste Framework Directive increased landfill costs for discarding construction and demolition waste, which improved construction processes to reduce waste and furthered the reuse and recycling rate of concrete, timber, and other construction materials (EMF, 2014a).

Using the OECD Classification of manufacturing industries into categories based on R&D intensity (OECD, 2011b) and the table of equivalences with the Nice Classes, proposed by Mendonça and Fontana (2011), it is possible to observe in Portugal a tendency towards applications in "low-tech" trademarks: i.e. applications in areas of traditional goods (Figure 29).

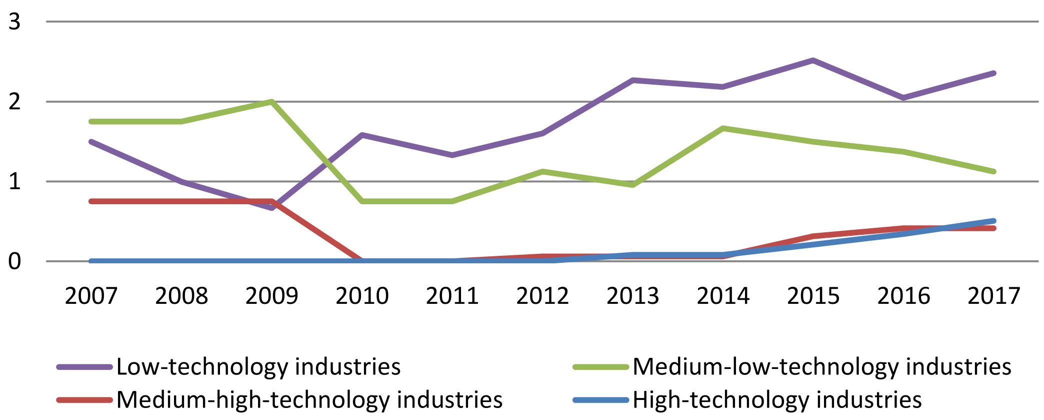

Figure 29 - Trademarks applications in "goods", break-down by technological intensity[107]

Concerning services classes, trademarks applications in those areas increased, particularly in the last years (for instance in 2015 and 2017 services have surpassed goods), which might be interpreted as evidence on a structural change of the economy. Increasing attention to CE issues may have created incentives for enterprises and producers to invest and develop new business models and services (even if slowly). Since CE is defined as an approach that proposes models for value creation through loops of reuse with a specific emphasis on the provision of functionality and "service" rather than ownership (EMF, 2012; Stahel and Reday-Mulvey, 1981), this do not appears a surprise but reinforce the potential of the trademark indicator as an interesting proxy of CE innovation in the service sector.

Considering that the service sector is a dynamic category of special importance towards a CE, what can its structure tells us? Using the distinction of services by its technological intensity (High-info and Low-info) and respective equivalence table with the classification of Nice proposed by Mendonça and Fontana (2011) it is possible to make some considerations. In the service categories (Table 41), most trademark applications are linked with the knowledge based/ information-intensive sectors services (Mendonça et al., 2004a; Miles, 2004), namely: advertising (Class 35); research (Class 42); and education (Class 41).

[107] Using a 4 year arithmetic moving average (i.e. simple average of a series over a defined number of time) as to smooth short-term fluctuations and highlight longer-term trends in the time series data. In the present case a 4 period was chosen as it contained a lesser mean squared error that a 2 and 3 year moving average.

Class	Descriptor	Applications	Share of service in total classes(%)
35	Advertising; business management; business administration; office functions.	9	8,4%
36	Insurance; financial affairs; monetary affairs; real estate affairs.	1	1%
37	Building construction; repair; installation services.	4	4,0%
38	Telecommunications.	2	1,5%
39	Transport; packaging and storage of goods; travel arrangement.	1	1%
40	Treatment of materials.	4	3,8%
41	Education; providing of training; entertainment; sporting and cultural activities.	5	4,7%
42	Scientific and technological services and research and design relating thereto; industrial analysis and research services; design and development of computer hardware and software.	7	7%
43	Services for providing food and drink; temporary accommodation.	4	3,4%
44	Medical services; veterinary services; hygienic and beauty care for human beings or animals; agriculture, horticulture and forestry services.	1	1,1%
45	Legal services; security services for the physical protection of tangible property and individuals; personal and social services rendered by others to meet the needs of individuals.	3	2%

Table 41 - Composition of trademarks service class applications

Also, as Figure 30 shows, the most sophisticated services have become increasingly more "trademarked" than the more traditional services, especially after 2014. The global financial crisis is clearly visible in 2010 with a slowdown in applied trademarks from both types of services, in line with what happened with the global number of requested trademarks in Portugal (Nunes and Matos, 2016). The period after the year 2014 marks a moment of inflection, with services surpassing goods and in high info sectors. Still it must be stressed that, as Nice classes are highly aggregated, that inevitably hinders the capacity to produce more precise conclusions (Mendonça et al., 2004a).

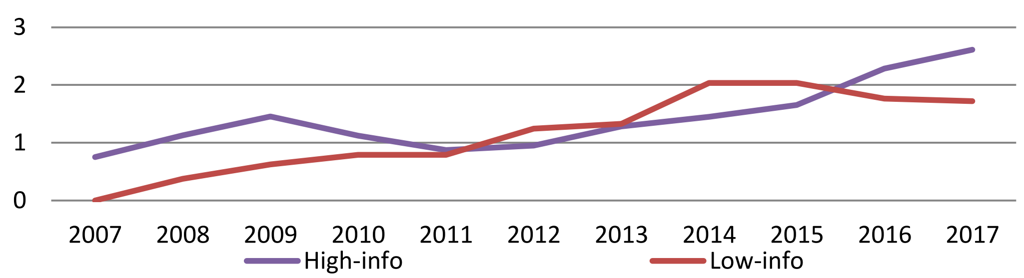

Figure 30 - Trademarks services applications, break-down by technology intensity[108]

[108] Using a 4 year arithmetic moving average (i.e. simple average of a series over a defined number of time) as to smooth short-term fluctuations and highlight longer-term trends in the time series data. In the

7.4.3. Actors in trademark applications

Concerning actors, a total of 34 organisations were found (Table 42). Three major groups were identified (using institutional sites to determine how the organisation called itself): companies/businesses; start-ups; and associations. “Companies” are established businesses and organisations with commercial interests; “Associations” include non-governmental organisations and institutions; “Start-ups” are usually young firms/ventures in the process of implementing a scalable business model (Moroni et al., 2015). There is, however, a gap of knowledge on the specific drivers of each one of these agents for applying for trademarks, and their motivations are still far from being clear.

Applicant name	Type or organisation	N of trademarks
A.B.O. - BANCA DE ÓCULOS ASSOCIAÇÃO DE SOLIDARIEDADE	Association	1
ADDVOLT, SA	Start-up	1
ANA CLÁUDIA DO COUTO FERREIRA	Start-up	1
ANTONIO JOSE RAMOS SILVESTRE FERREIRA - “Vale da Rosa”	Company	2
ASSOCIAÇÃO BLC3 - PLATAFORMA PARA O DESENVOLVIMENTO DA REGIÃO INTERIOR CENTRO	Association	1
BOOK IN LOOP, LDA.	Start-up	1
CIDADE COM PERFIL - ECOLOGIA URBANA, LDA	Start-up	2
COOLFARM	Start-up	3
ECO SOLUTIONS - COMÉRCIO E INDÚSTRIA, UNIPESSAL, LDA	Company	1
ECOCHIC PORTUGUESAS - FOOTWEAR AND FASHION PRODUCTS	Start-up	3
ENTRAJUDA - ASSOCIAÇÃO PARA O APOIO A INSTITUIÇÕES DE SOLIDARIEDADE SOCIAL	Association	1
FERNANDO RUI RIBEIRO DA SILVA – “Moinho de Chuva”	Company	1
FORTE TRADIÇÃO - GESTÃO IMOBILIÁRIA, S.A.	Start-up	2
FRESH LAND	Start-up	4
GOOD AFTER - SUPERMERCADOS, LDA.	Company	1
JULAR MADEIRAS	Company	25
LIPOR - SERVIÇO INTERMUNICIPALIZADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	Company	11
LOGOPLASTE INNOVATION LAB, LDA	Company	1
LOPES & GERKEN, LDA.	Start-up	1
NAE - COMÉRCIO E DISTRIBUIÇÃO DE CALÇADO VEGAN, LDA.	Company	1
NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	Company	11
NORMA SUSANA PINTO DA COSTA E SILVA	Start-up	1
OIL2WAX INNOVATIVE MATERIALS	Start-up	9
PH ENERGIA, UNIPESSOAL LDA	Company	1
PORCELANAS DA COSTA VERDE, S.A.	Company	2
QUINTA DA LIXA - SOCIEDADE TURISMO, UNIPESSOAL LDA.	Company	1
RICARDO MIGUEL MELO MARQUES	Start-up	1
SOJA DE PORTUGAL	Company	2
TÂNIA SOFIA MOREIRA ANSELMO	Start-up	1
TDCORK TAPETES DECORATIVOS COM CORTIÇA, LDA.	Start-up	2
VANGUARDCHAPTER, LDA.	Start-up	1
VILARTEX - EMPRESA DE MALHAS VILARINHO, LDA.	Company	2
VIRTUAL POWER SOLUTIONS, S.A.	Company	5
WISE CONNECT, UNIPESSOAL, LDA	Start-up	1

Table 42 - Overall organisations identified

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present case a 4 period was chosen as it contained a lesser mean squared error and mean absolute deviation that a 2 and 3 year moving average.

Overall, companies have the greater number of trademarks applications (64% of the total applications), with associations having only residual numbers (3% of the total applications - see Figure 31). What is interesting to note is also the high number of trademarks that "start-ups" are applying for (33% from the sample).

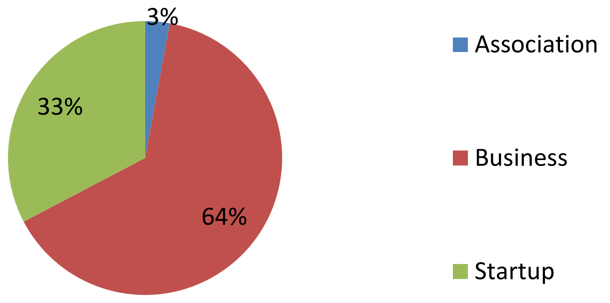

Figure 31 - Overall number of trademarks per type of applicant (%)

Considered vital in economic development and job generation, start-ups are particularly linked with the introduction of disruptive goods and services that overturn the positions of incumbent firms. Especially in services, start-ups are prone to be innovative (Criscuolo et al., 2012). Start-ups have indeed been linked with the emergence of sustainable business model innovation, e.g. Zipcar (car sharing) and Airbnb (home and room rental) (Bocken, 2015). This may suggest a reinforcement of the entrepreneurship structures in CE business models in Portugal, especially in the last period 2013-2017 (Figure 32).

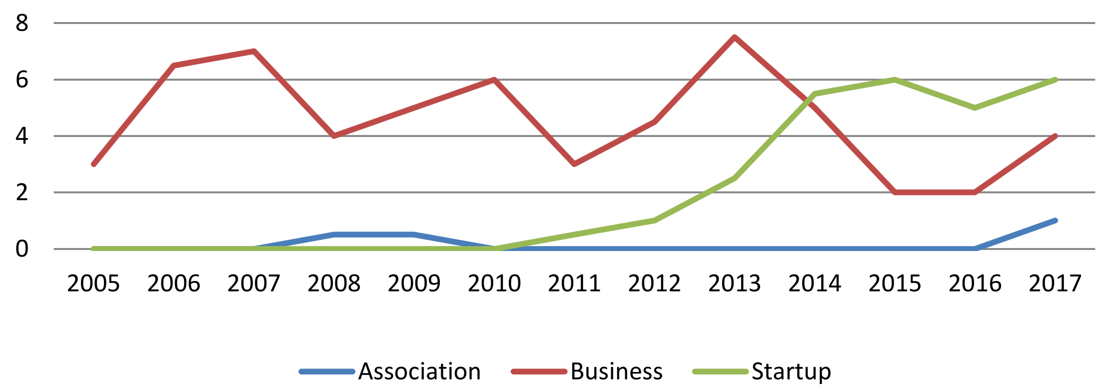

Figure 32 - Overall evolution of number of trademarks per type of applicant[109]

[109] Using a 2 year arithmetic moving average (i.e. simple average of a series over a defined number of time) as to smooth short-term fluctuations and highlight longer-term trends in the time series data. In the present case a 4 period was chosen as it contained a lesser mean squared error and mean absolute deviation that a 3 and 4 year moving average.

7.4.4. Trademarks as a "circular" innovation proxy, an appraisal of the lessons learned so far

Despite technological EI's higher recognition as a pathway for the transition to a CE (de Jesus et al., 2018) other "softer" service and marketing innovation dimensions are increasingly being acknowledged. Indicators based on symbolic and other intangible assets have a potential for further advance in the future, but they need to be developed while accepting their boundaries and methodological limitations. With that consideration in mind trademarks were used for assessing pro CE innovation. This complementary indicator of soft innovation offers an operative approach for studying, monitoring and piloting "deep transition" in areas were other indicators are less prone to be revealing.

For a sample of Portuguese actors, the proposed trademark applications analysis enabled the observation of several trends. First, the uneven dynamics signal a demand-side very vulnerable to the macroeconomic context, even if the total number of applications increased. Secondly, the applied trademarks mainly concern "goods" and are focused particularly in the clothing and construction sectors, in tune with the sectoral identification of priorities and opportunities within a CE. Nevertheless, a slow structural change seems to be underway as in 2015 and 2017 services surpassed goods in trademarks applications. This may point to an increasing interest of CE aware actors towards services, following the European Commission's Communication *Towards a circular economy: a zero waste programme for Europe* of 2014, and the 2015 *EU Action Plan for the Circular Economy* (EC, 2015), where the provision of functionality and "service", rather than ownership were emphasised as essential in a CE. Third, a strengthening of entrepreneurship structures in CE business models in Portugal may also be perceived in the analysis, even if especially focused on small agents and start-ups.

These stylised facts resonate to the patent analysis suggesting that a socio-technical transition in the Portuguese case is starting, signalling an operative, albeit slow, transformation on the demand-side and unveiling systemic failures in terms of entrepreneurship structures. These findings reinforce the potential of the trademark indicator as a complementary proxy of pro CE innovation. Specifically concerning the incremental, service-oriented, SME-intensive progress towards a CE this methodology seems consistent, informative and enlightening. For instance, the definition of public policies in Portugal for the implementation and dissemination of a CE could benefit from this input to redirect its action. Bearing in mind the fragile entrepreneurship structures in CE business models (small agents and start-ups), further improving stakeholder involvement and cooperation should be a priority. Also, it would be important to address financial barriers, namely financing constraints, which remain very hard to overcome for small organisations. For example, not only through government programmes supporting activities related to the CE, but also by informing and helping organizations to access already existent and alternative financing instruments.

Nevertheless, considerations regarding cooperation and networks are the main limitations of this methodological analysis. In this regard other indicators could be used to complement these findings. Some surveys already present some data regarding EI activities developed by SME's toward changing and adapting business models according to the principles of a CE (TNS, 2016). Also, in a demand side/social perspective, focused on sustainable consumption and lifestyle, other societal behaviours indicators could aid in this debate in order to understand the level of citizen/consumers/users engagement and participation in the CE, as citizens' willingness to participate in those alternative forms of consumption/services is deemed essential to the success and uptake of a CE transition (TNS, 2014).

Regarding future research avenues, other indicators not tested in the present analysis should be considered, not only design based proxies, but also other trademark base indicators like "Collective Trademarks" (certification). Metrics like eco-design and environmental certifications are still to be substantially used in CE assessment. For instance, the recent Eco-Design Directive, promoted within the legislative proposal of the Circular Economy Action Plan has been stated as contributing to positive environmental performance and enterprises competitiveness. Nevertheless, the instrument has also received criticism regarding its incomplete coverage and slow development (Domenech and Bahn-Walkowiak, 2018). Other examples are the EU Ecolabel Scheme and the EMAS, environmental certification mechanisms, recognised by their relevance in the transition towards a CE, but still underexploited (EC, 2017d, 2017e). These may be paths for further exploration.

The case study application could also benefit from extending the approach through comparative studies to encompass several realities within a given region or across regions. As mentioned in the methodological section, other lists of renowned enterprises and other actors engaged in CE efforts are already available (for instance the EMF CE100, and the World Economic Forum's "The Circulars" awards). Those could be used to refine the methodological considerations regarding the use of trademarks as a "soft" pro CE innovation indicator, and to further compare countries dynamics towards a CE.

7.5.Main Conclusions

Despite recent efforts, monitoring and assessing the performance of a CE still poses a significant challenge. A knowledge gap remains in identifying CE empirical indicators, even more pronounced when assessing CE "transformative innovation", as well as when analysing a "softer" kind of innovation related with marketing and service solutions.

Addressing the innovation metrics agenda from the perspective of a CE towards sustainability, this chapter reviewed non-traditional "soft" innovation indicators potential for measuring and monitor the deep transition towards a CE. It seems clear that "soft" indicators as design metrics, trademark analysis and environmental certifications, have yet to be substantially used in this field.

Within these indicators, trademarks were identified as a meaningful proxy of "soft" pro-circular innovation. A proof-of-concept empirical application of this approach was carried out on the basis of an original and purposely-build dataset, adding to the previous use of patents as a "hard" proxy in the analysis of a "national innovation system with "circular characteristics", with Portugal as the case-study. For a sample of Portuguese actors, patterns were uncovered that may provide guidance for the analysis of pro-circular actors elsewhere. This analysis shed light on an uneven demand-side dynamics and an entrepreneurship structure in CE business models largely made up by small agents and start-ups, with "circular" trademarks applications especially directed to traditional/low-tech goods and sophisticated/informationally-intensive services.

Trademark analysis, despite all the methodological difficulties, appears as an interesting indicator that may point to dynamics difficult to capture by other indicators, namely patents. This is a dynamic field with a wide range of opportunities for further research. Since EI and CE have a wide application, the way in which they are used and understood by different stakeholders varies. As a result, a better understanding of these diverse perspectives is needed in order to better tailor strategies and policies. For example, the role of consumers as “part of the supply chain” and “innovative agents” in the development of a CE has not yet been properly addressed.

PART III – LESSONS FROM THE ECO-INNOVATION/ CIRCULAR ECONOMY NEXUS

The limitations of the contemporary “linear economy” continue to puzzle analysts and decision-makers in the face of growing evidence of climate change and environmental depletion. The assumptions discussed in this research focus on the circular economy (CE) approach by means of “transformative” eco-innovation (EI) pathways. This effort led, first, to an analysis of definitional issues regarding CE and EI and the nexus between those concepts (theoretical/conceptual). Next, and considering the need to assess convergence to circularity, potential indicators of “transformational” socio-techno-economic change were operationalised to evaluate how EI is geared to the transition to a CE (i.e. how CE-inducing EI can be measured - empirical approach).

The third part of this work added a more “normative” component, placing emphasis on implications and on discussing previous insights’ importance. At this point, the goal is to “make sense” of the overall findings, answering to the research questions, and also debating implications for nations (specifically to Portugal, a transversal case study in the research) in a globalised world (debating pertinence of this thematic within the globalisation studies agenda).

Since anticipating possible developments may enable better responses to complex societal problems and to take advantage of the arising investment opportunities (Konu, 2015; Linstone and Turoff, 1975), understanding more about CE implementation, applicability and future developments, within the ongoing global debate regarding sustainability, is of great importance. Building on the relevance sustainability has acquired both as a public policy tool, as well as an entrepreneurial strategic objective (Washington, 2015), the contribute of the more targeted CE approach and its close relation with “transformative” eco-innovation (EI) may be useful to fine-tune public policies towards the desired transition. Chapter 8 starts by using a Delphi study to gather the insights of institutional sectors (public, business, academic actors as well as NGOs) regarding key future priorities in the CE approach and its singularities within the sustainability debate. Chapter 9 “brings it all together”, discussing key findings, implications, research limitations, as well as prospects for further research.

CHAPTER 8

UNDERSTANDING THE PRIORITIES OF THE ECO-INNOVATION PATHWAY TO THE CIRCULAR ECONOMY TRANSITION

Transition to sustainability is by no means automatic, even in the age of "smart growth" (Foray, 2014) and the so-called "industry 4.0" (Schwab, 2017). Transition is a concept-dependent and strategy-intensive holistic manoeuvre facing existential analytical and strategic challenges regarding the specific pathways (Kanie and Biermann, 2017). This engages explicitly with the need for conceptual clarification and the opportunities yielded by new evidence and the urgency of relevant practical implications. This chapter tries to reduce that uncertainty by recurring to foresight, defined here as an organised sense-making process that can be deployed to advance understanding regarding the goals and guide-posts of transition (Mendonça et al., 2012; Mendonça and Sapio, 2009). It explores "Circular Economy" (CE) as the target of transition, attempting to generate a positive contribution by scoping pro-circular perspectives and prospects. Our hypothesis is that eco-innovation (EI) constitutes a major enabler of such a transition process (de Jesus et al., 2018; de Jesus and Mendonça, 2018). Two objectives guide this effort: first, to ascertain the specificities of CE within the sustainability debate; second, the key priorities that will foster a CE. The foresight approach to knowledge discovery is held as instrumental for envisioning the "end-state" (clarifying what CE means) and the "pathways" of transition (charting systemic eco-innovation routes).

The precise methodological solution suggested in this chapter, as a way to cut through the ambiguities of the present and deal with the lack of knowledge regarding next practices, is a Delphi policy-learning experiment. Under conditions of radical uncertainty, Delphi studies emerge as a generative collective intelligence process for arriving at shared meanings of future goals and at new policy priorities (Konu, 2015; Linstone and Turoff, 1975). Assuming that the key features of the CE can be best addressed by those actively involved in its development and dissemination, a three-round Delphi study was deployed, engaging a rich array of actors, counting with 29 experts from 11 countries. In the next sections, this chapter will discuss the: global debate on sustainability and how CE gained ground within it (8.1 and 8.2); methodological underpinnings of a Delphi approach to explore this issue (8.3); empirical results and insights distilled bearing on public policy (8.4).

8.1. Sustainability multiple definitions and applications: Conventional versus transformative approaches

Growing scientific evidence on climate disruptions and natural capital depletion has been furthering the sustainability debate (Crist and Rinker, 2010; OECD, 2012; UNDESA, 2011). At the same time that population doubled and GDP sharply increased following the Industrial Revolution, the global environment endured unprecedented negative impacts (Crist, 2012; OECD, 2012). The world witnessed an explosive surge in the usage of energy and resources, degradation of ecosystems, biodiversity loss, and sheer pollution affecting both humans and other species (EIO, 2011; UNDESA, 2011). Concerns led to research and social mobilisation and, especially since the 1960's, to the questioning of the (modernist) ideas of "growth" and "development" (Geissdoerfer et al., 2017).

The sustainability debate is thus not a recent one, The United Nations Conference on the Human Environment (UNCHE) – the Stockholm Conference – was one of the first international fora to emphasise the right to "an environment of a quality that permits a life of dignity and well-being" and the responsibility "to protect and improve the environment for present and future generations" (UN General Assembly, 1972 Principle 1). In that same year, the first edition of *Limits to Growth* (the classic report of the Club of Rome) attracted vast international attention and remains a milestone in the environmental debate (Meadows et al., 2004). The fully-fledged concept of "sustainable development" then came in 1987 as the major plank of the Brundtland Report *Our Common Future*, an outcome of the Conference on the Human Environment by the United Nations World Commission on Environment and Development (WCED), where the most recognised definition of sustainability as of yet was presented: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987, p. 43).

Sustainability is now understood in a wider sense, including environmental (pollution, waste, resource use), social (health, well-being) and economic (efficiency, competitiveness) aspects. Nonetheless, the concept has remained fragmented; some authors counted more than 300 definitions of "sustainability" (Johnston et al., 2007). "Sustainability" has moreover been employed as an all-encompassing expression, used indistinguishably in rather diverse contexts, by different actors, with distinct agendas, and sometimes diverging only very slightly from standard "business as usual" *status quo* (Johnston et al., 2007; Washington, 2015). This lack of a clear definition and its rhetorical overstretch led to some consequences. As Engelman (2013) pointedly remarked: a portion of the sustainability conversation became mere "sustaina*babble".*

A point of discussion in this debate concerns "weak" and "strong" sustainability interpretations (Dietz and Neumayer, 2007). The concept of *weak* sustainability came from the work of economists like Solow (1993, 1974) and Hartwick (1978) who postulated the possibility of trade-offs: the interchangeability of capital (the substitution of natural capital for other types of capital, namely human capital). This conception is based on the compatibility between economic development and environmental sustainability, on the commensurability of distinct forms of "capital" and is linked to the so-called environmental economics school of thought. In this perspective, technical environmental problems are deemed to be manageable *on the margin* (Ekins et al., 2003). This perspective remains the common approach to sustainability by most governments (Washington, 2015, p. 40). As for the *strong* version it states that human capital and natural capital, while complementary, are not endlessly interchangeable. This perspective, linked to the ecological economics school of thought, considers that trade-offs are not always appropriately mapped – it recognises both the political economy of such choices, as well as the unaccounted services and life support functions of natural capital (Costanza and Daly, 1992; Washington, 2015). This is a perspective that advocates structural changes in society and the importance of new monitoring metrics of "true" sustainability (Dietz and Neumayer, 2007). However, concepts such as "degrowth"[110] or "steady state economics"[111] have been proving difficult to operationalise in the currently hypercompetitive global capitalist market scene (Bergh, 2001).

Questions persist regarding the nature of sustainability and how to achieve it (Markard et al., 2012). Despite the plethora of definitions and approaches it must be stressed that sustainability (in its various guises) still figures as a "merit good", i.e., a valuable societal goal from the point of view of national and international polities and

[110] Degrowth is defined as a voluntary reduction of society's throughput aiming to achieve social equity and ecological sustainability (Alexander, 2012; Asara et al., 2015; Charonis, 2012). It is "an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level, in the short and long term" (Schneider et al., 2010, p. 511).

[111] Steady State economics is a similar with "degrowth", as it also advocates environmentally sustainability and social equity (Charonis, 2012). It can be characterised as an economy that experiences neither growth nor decline, but a "steady" rate of throughput (Charonis, 2012; Czech and Daly, 2004).

large economic institutions. Its relevance is indisputable, and as O'Riordan (1993, p. 48) puts it, it remains a "political concept as persistent as are democracy, justice and liberty". In turbulent times, building on the continuous legitimacy of this *strong* strand of sustainability goals is both pertinent and impertinent (Ekins et al., 2003; Washington, 2015).

8.2.Circular Economy within the sustainability debate: similarities and differences

The "Circular Economy" is an approach within the sustainability debate (Murray et al., 2017). Inspired in natural ecosystems, it has been defined by its opposition to a harvesting-wasting economic model. This is an approach deeply associated with previous contributions related to the scarcity of the Earth's resources (see Boulding, 1966; Georgesçu-Roegen, 1971; Meadows, 1972). What is new is the tentative scaling-up of the idea of a closed-loop system (Pearce and Turner, 1990; Stahel, 1986; Stahel and Reday-Mulvey, 1981) and its application to industrial systems (Ayres and Weaver, 1998; Frosch and Gallopoulos, 1989). This framework builds on concrete measures to address resource depletion, unsustainable consumption and mismatches in between. CE emphasises the minimisation of the use of non-renewable materials, the elimination/valorisation of waste and the identification of new economic strategies (production-service stratagems, innovative business models, etc.) (Kopnina and Blewitt, 2015). It is not seen as a mere "preventive" approach, since it intends to be "restorative" (Murray et al., 2017).

Broadly, CE has been defined as an integrative approach by re-matching, re-balancing and re-wiring industrial routines and consumption habits, supporting a renewed socio-technical template for economic development in an environmentally sustainable trajectory (de Jesus and Mendonça, 2018; Geissdoerfer et al., 2017; Murray et al., 2017). By allowing for distinctively new combinations of consumption, production, and distribution, CE's multidimensional approach appears a high, but reachable, socio-technical aim.

Against the sustainability backdrop, the *circular* conception of the economy has been also argued as compatible with the notion of *strong* sustainability: "the emphasis is not on substitutability and aggregate capital, as in the neoclassical linear conception, but rather on the different logic behind the valuation of natural resources on the one hand, and manufactured capital on the other hand." (Martins, 2018, 2016, p. 32) CE and "sustainability" can both be characterised as interdisciplinary approaches emphasising global and long-term trajectories. Both call for the integration of environmental aspects and "development" issues, implicitly emphasising innovation as a transition vehicle (Schot and Kanger, 2016). However, CE arguably refers more directly to *transformative innovation* (which we interpret as *deep green* innovation - or EI for short) and demand-side considerations (which we interpret as creative *usage adaptation*, i.e. socio-institutional dimension). That is, on the one hand, the migration to a CE implies EI: environmentally-sensitive innovation that addresses sustainability concerns and has positive ecological effects (Costantini et al., 2017; Jabbour et al., 2015).[112] But, on the other hand, it also requires the redesign of societal regimes in terms of official and tacit rules, as well as individual and collective behaviours, favouring the emergence of new business models (Geissdoerfer et al., 2017).[113] Hence, "transformative" pro-CE innovation is thus a Schumpeterian *new combination* of "harder" (R&D-driven products, cost-cutting processes) and "softer" (changes in culture and business models) knowledge. Fusing technological and non-technological change into a new clean and congruent techno-paradigm has been referred as "systemic EI" (de Jesus and Mendonça, 2018). [114]

Overall, CE objectives are clear enough (limit inputs, close the loops, avert waste), but their attainment is complex and multifaceted. As Sauvé (2016, p. 55) stresses, CE "will not be immune to failures, misuse, ambivalence and greenwashing", being susceptible to misappropriations by the unsustainable business-as-usual model. As it is, CE remains constrained by traditional economic thinking disputing strong sustainability interpretations (Kopnina, 2018). Also, CE is not a consensual concept either, and its definition is still in a state of flux (Geissdoerfer et al., 2017; Homrich et al., 2018; Kirchherr et al., 2017; Korhonen et al., 2018a; Murray et al., 2017). As this is an emergent agenda, a cautious definition is needed to avoid oversimplifications and empty generalisations that may hinder the usefulness of the concept (Murray et al.,

[112] EI appears here as a way to "(…) move societies from the extract, consume, and dispose system of today's resource use, towards a more circular system of material use and re-use with less total material requirements overall." (EIO, 2012, p. 20).
[113] As Braungart and McDonough (2002) argue, a fourth "R" it is necessary besides "reduce, reuse and recycle": regulate.
[114] For further reference regarding innovation systems and techno-economic paradigms see (Castellaci et al., 2005).

2017). As for EI, it is considered “a prime candidate for ‘new mission’ policies, to deal with (interrelated) societal challenges of climate change, resource efficiency and energy/resource scarcity.” (Kemp, 2011, p. 2) As such, future-oriented knowledge on how to direct “system innovation” to “circular” practices acquires an increased importance. Analytical considerations regarding these issues are, therefore, of particular interest and should inform policy building. In particular, in what concerns extracting the key future priorities and implications of the CE-EI relation to socio-cultural agents, organisational strategies and policy priorities.

In that context, foresight methodologies may have something to add to this discussion, especially when pooling the experiences of agents already actively engaged in these dynamics. The premise is that the iterative and interactive judgment of a selected group of specialists will harness insights from their field and capture non-explicit knowledge (Gordon, 1994; Wright and Giovinazzo, 2000). The following section will further the debate on the methodological applications of such an anticipatory exercise, namely, the Delphi method.

8.3. Using the Delphi method - Methodological considerations

8.3.1. Foresight as a knowledge discovery technique

The Delphi method was initially developed by the RAND Corporation, in the context of the Cold War, as a foresight military tool for operations research. The name is an analogy with the Greek oracle known for offering insight into the future of whom would ask (Cuhls, 2002; Hsu and Sandford, 2007). In the 1960s, this method gained popularity in forecasting research and relevance in the academia (Linstone and Turoff, 1975). Nowadays, the Delphi method has been especially used in long-range futures studies, applied to S&T, economic and financial settings, and civic planning in areas like infrastructure, public transportation, health care and education (Cuhls, 2002; Giannarou and Zervas, 2014). Other applications of this method are seen in program planning, needs assessment and policy determination (Hsu and Sandford, 2007). It is also identified as a suitable method for business management and strategic planning, addressing the need to muster the collective to deal with trends and turns in the evolving decision space (Konu, 2015; Linstone and Turoff, 1975; Mendonça et al., 2009, 2004b).

8.3.2. Methodological advantages and limitations of the Delphi approach

The Delphi method focuses on gathering the opinions of experts regarding new concepts or complex problems. It is a "structured conversation", especially suited to answer questions where there is incomplete and uncertain understanding (Giannarou and Zervas, 2014; van der Heijden, 1996; Wright and Giovinazzo, 2000). The use of the Delphi method is particularly suited to exploratory studies, especially in emerging themes, when there is a lack of data or frame of reference concerning determinants of future events and developments (Szpilko, 2015). It is, therefore, an expert survey in two or more successive rounds, based on feedback information between each round, allowing the participants to revise and calibrate their previous considerations in the light of other revealed bits of knowledge (Konu, 2015; Linstone and Turoff, 1975).

The method removes geographic barriers and is based on the anonymity of respondents (Wright and Giovinazzo, 2000). The same experts assess the same matters several times without "losing face" or pressure exerted by "dominant"/influential panel members (Gordon, 1994). This technique is thus intended as a filter to group biases enabling the actors to be more problem-solving oriented (Hsu and Sandford, 2007). It seeks agreement, dialectical disagreement, sharing of insights and collective build-up of informed conclusions on critical issues (Cuhls, 2002; Gordon, 1994; Keeney, 2010). It conveys both qualitative and quantitative results (Barnes and Mattsson, 2016; Cuhls, 2002).

With several types of applications, the Delphi can be used to examine the pros and cons of policy or business options, to clarify motivations and bottlenecks or to identify developing causal relationships in complex economic or social issues. However, what makes the Delphi a compelling method is not its universal suitability, but its adaptability to the specific circumstances of the addressed problem. If a question proves difficult to analyse through other methods, it can benefit from a multi-expertise collective method of data gathering like the Delphi (Linstone and Turoff, 1975). While standard surveys reveal information regarding "what is", Delphi ones focus on "what could be" (Miller, 2006).

The Delphi method is not without limitations. It is very time-consuming and without a conventionally agreed design (Keeney, 2010). Also, regarding the selection of experts, it can be subject to methodological concerns regarding what a "specialist" truly is. Therefore, it must be carefully designed, regarding its questionnaire, consensus nudging and expert choice (Geist, 2010; Hasson et al., 2000). The methodological choices taken to minimise these limitations are addressed in the following subsections.

8.3.3. Panel composition

As there is not a unique Delphi formula, but a series of attributes that can be tailored to fit specific research needs, the design of such an exercise must be made explicit. The selection of experts is one of the most important tasks as it directly impacts on the quality of the results. Eligibility must be ascertained with relation to backgrounds and experience on the theme under discussion (Hsu and Sandford, 2007). Also, it is suggested that a somewhat heterogeneous sample of specialists should be invited from different backgrounds: academia, business, policy-making (Cuhls, 2002).

For the present exercise the experts were required to have comprehensive understanding of the CE, and were identified mainly through literature reviews (de Jesus et al., 2018; Geissdoerfer et al., 2017; Jabbour et al., 2017; Murray et al., 2017), participation in CE events[115], as well as snowball technique, using recommendations from previously identified specialists (contacted experts were asked to nominate others) - Table 43.

Types of stakeholders	Criteria for sourcing panel members
International organisations, NGOs and social enterprises leaders	- Identified in the CE literature - Organisations that participated in CE conferences and workshops - Snowball identification
Practitioners /Enterprises	- Enterprises with CE links identified by the EMF (EMF, 2018) - Enterprises identified in the CE award program “The Circulars” (The Circulars, 2017) - Enterprises that participated in CE conferences and workshops
Scientific community	- Identified in the CE literature - Lecturers in CE programs (universities of Bradford, Cranfield and Delft) - Participants in scholarly CE events - Snowball method

Table 43 - Expert panel definition.

[115] Like the “16th European Forum on Eco-innovation – Wasted Potential! Towards Circular Economy in Cities” (April 2014, Hannover, Germany); and the “Global Cleaner Production & Sustainable Consumption Conference” (November 2015, Sitges, Spain).

Regarding the size of the pool of specialists, the literature advice varies from several hundred to a dozen of experts. Notwithstanding, panels having around 10-30 experts seem to be the most frequent (Hsu and Sandford, 2007; Keeney, 2010). As the sample should not be too small, to ensure representativeness, but also not too big that it becomes unworkable (low response rates and time constrains), the objective in our case was to stabilise on a set of around 15 to 20 experts. The first round counted initially 29 experts (on the expectation of subsequent drop-out), 21 continued to the second round and 17 completed all three rounds (Figure 33).

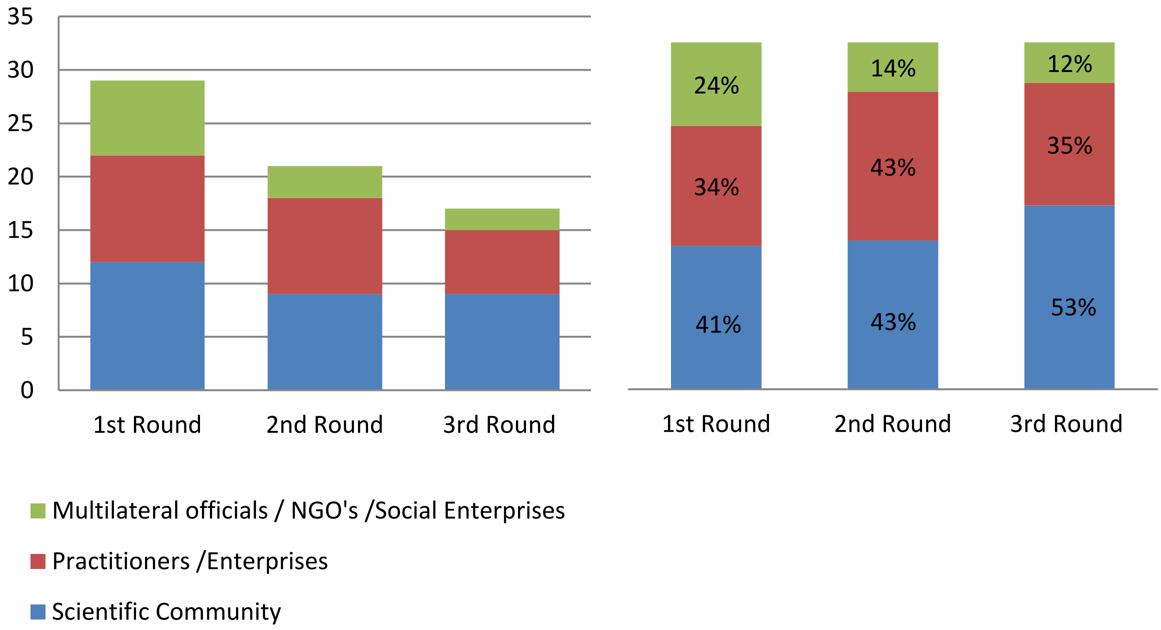

Figure 33 - Respondents per Round, total number and distribution.

Geographical considerations were also minded as to gather experts working in several different locations. Even though several Asian[116], African[117] and South American[118] experts were contacted, they were unable to participate (especially due to time and schedule constraints). Specialists working on Europe and North America made up the majority of the specialists that accepted to participate (Figure 34).

[116] Namely Chinese (3), Japanese (2) and Indian (1) researchers.
[117] Namely a South African researcher (1) and an International organisations/NGOs/Social enterprises official (1).
[118] Namely Brazilian researchers (2) and an International organisations/NGOs/Social enterprises official (1).

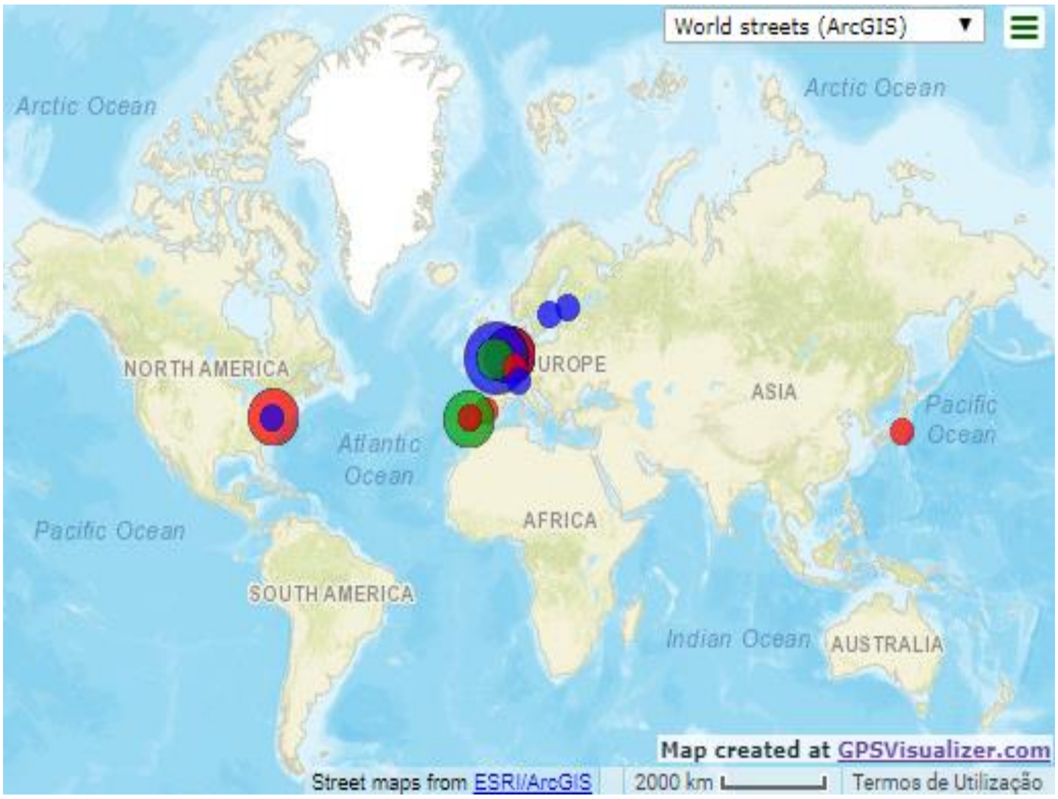

Figure 34 - Global distribution of CE experts that finished all three rounds of Delphi exercise per type: scientific community (red), from business (blue) and other institutions (green).
Note: N=29. Each circle represents a country, focusing on the capital city, and its relative size the number of experts that responded to the first round. Countries: Belgium, Finland, Japan, Luxembourg, Netherlands, Portugal, Spain, Sweden, Switzerland, UK, USA. Map generated in gpsvisualizer.com.

The experts that agreed to participate in the Delphi were asked to self-define their expertise (thematic field or business area in case of companies) in order to enable a more accurate panel categorisation (see Figure 35, Figure 36, and Figure 37).

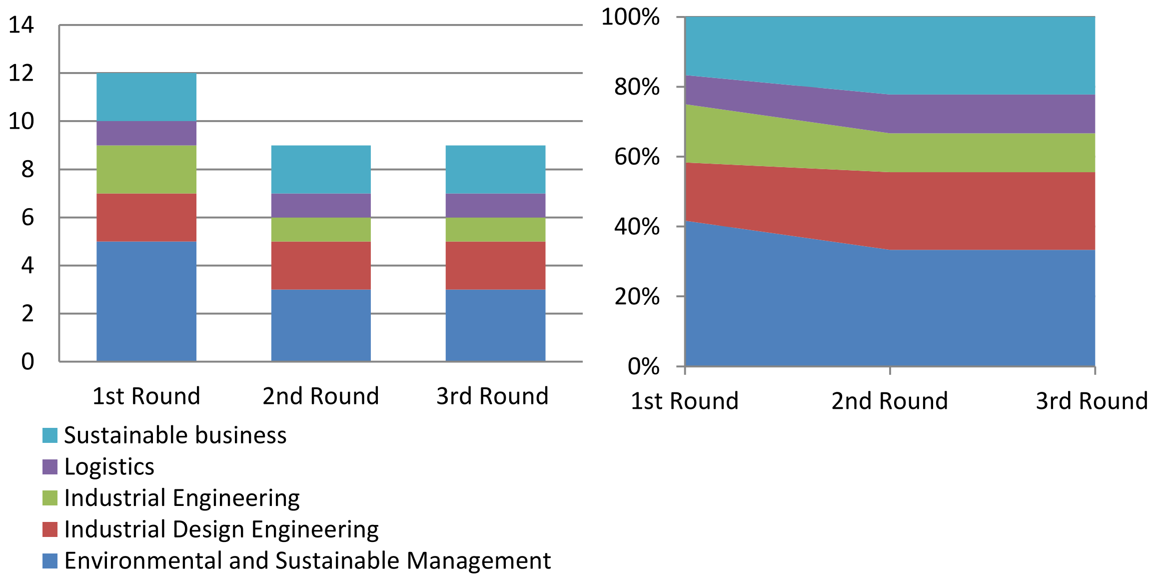

Figure 35 - Principal areas of research of Academic respondents, per round (total and %).

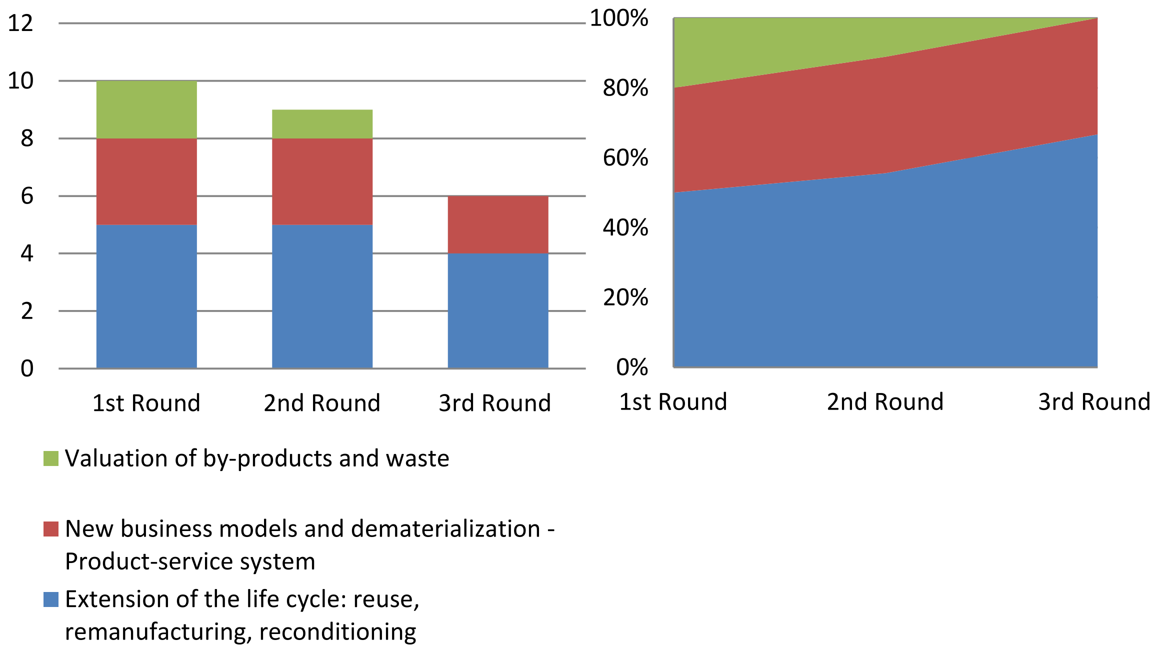

Figure 36 - Principal circular strategy of Business respondents, per round (total and %).

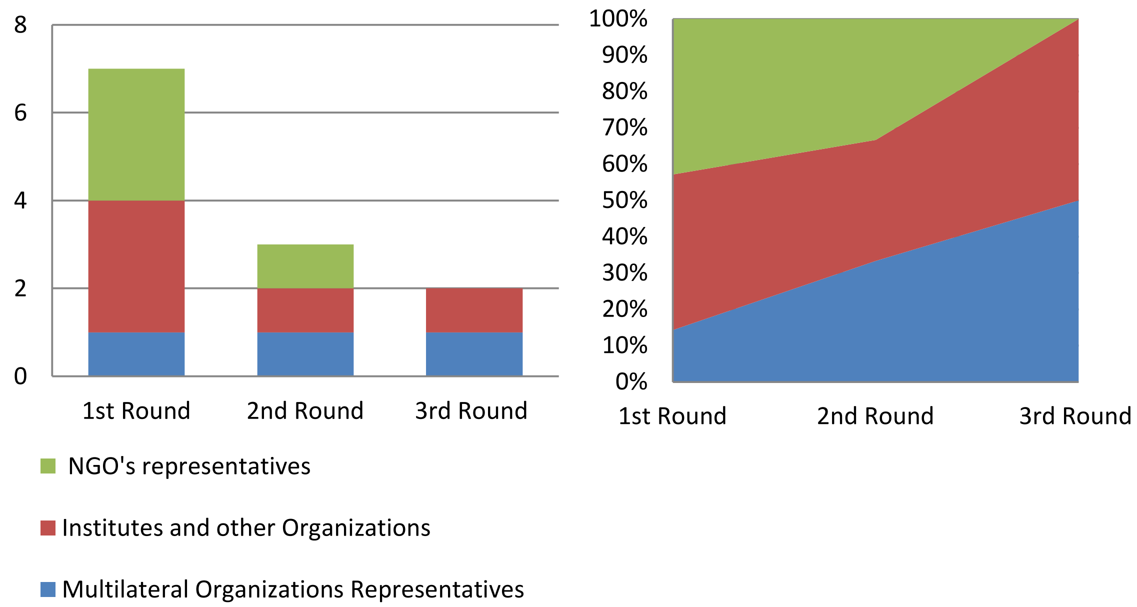

Figure 37 - Public (international) institutions respondents categorisation, per round (total and %).

8.3.4. Data collection and analysis

Before the first round, data was gathered through literature review (de Jesus et al., 2018; Geissdoerfer et al., 2017; Jabbour et al., 2017; Murray et al., 2017). Delphi data was then collected from July 2016 to January 2017, in three rounds (Figure 38).

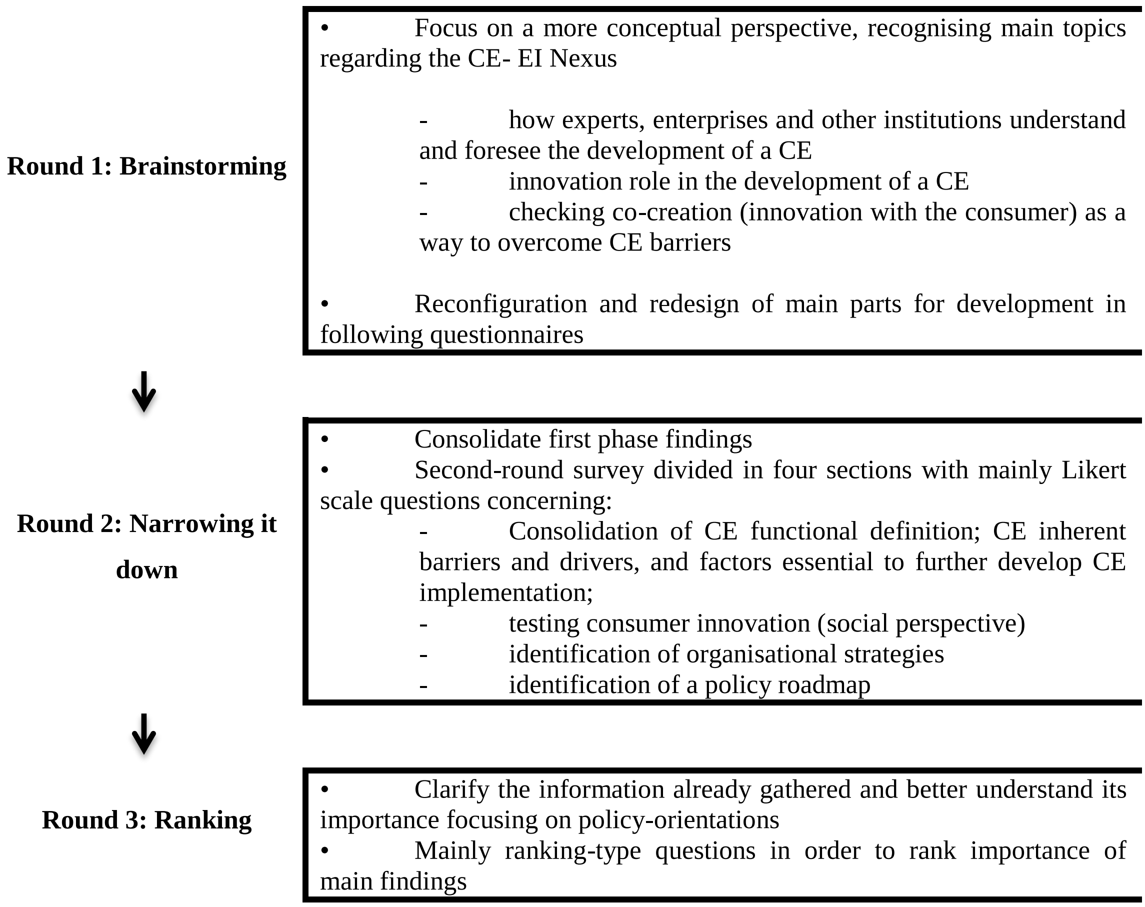

Figure 38 - Delphi process
Note: Inspired on Okoli and Pawlowsky (2004) and Schmidt et al. (2001).

Three rounds are often considered satisfactory to gather the needed information and/or reach consensus (Hsu and Sandford, 2007) and in the present case it was also assumed that additional rounds would not enhance the results (following also the guide lines of von der Gracht, 2012). The Delphi invitation sent to CE “experts” (Appendix 8), reflections on the use of the Delphi method and the links between the rounds (Appendix 9), rounds structure (Round 1 – Appendix 10; Round 2 and 3 Appendix 11), and an overall summary of results (Appendix 12), are included as Appendices.

Each round survey data was captured with Esurvey[119] and subject to quantitative and qualitative analyses. Standard spreadsheet software was employed in the calculation of mean, median, standard deviation, inter-quartile range, percentages, and Kendall's W. The statistics enabled an indication of expert convergence and of the relative importance of the issues raised. The qualitative analysis of the open-ended questions sharpened the comprehension of each key point and provided context to the interpretation of the quantitative results. As the present analysis seeks to understand CE, but also provide policy implications (this is a variation of a "policy"/"decision" Delphi with generative characteristics, i.e. a policy-learning Delphi – see Table 44), consensus was not specifically sought, but if found it was also not disregarded.

Delphi Type	Focus	Literature examples
Classical Delphi	Focused on gathering knowledge and reaching consensus	The classical Delphi method is a series of paper–pencil questionnaires administered through the mail (…)" (Geist, 2010, p. 149). "In the course of its application, a common opinion is pursued, a consensus among experts." (Szpilko, 2015, p. 333) "Uses factual based information to elicit opinion and gain consensus (e.g. first round based in literature on the subject); uses three or more postal rounds." (Keeney, 2010, p. 232)
Policy Delphi	Focused on identifying possible solutions to a particular problem.	"The Policy Delphi seeks to generate the strongest possible opposing views on the potential resolutions of a major policy issue." (Linstone and Turoff, 1975, p. 80) "Delphi Policy is a recognized instrument for the analysis of a specific problem in the economy, society and science, but it is not a mechanism for decision-making." (Szpilko, 2015, p. 333) "Exploring a matter of interest or with political consequences." (Alvarez Etxeberria et al., 2015, p. 46)
Decision Delphi	Focused on decision-making rather than arriving to a consensus	"Same process usually adopted as a classical Delphi; focuses on making decisions rather than coming to consensus." (Keeney, 2010, p. 232) "(..) the aim is to gain information to support decisions related to new service development (finding new service ideas, evaluating and selecting potential service/product ideas to be developed further) instead of gaining consensus on certain issue." (Konu, 2015, p. 43)

Table 44 - Examples of types of Delphi

[119] Esurveycreator - Online survey software

As the literature is not unanimous on consensus metrics (see on this regard Giannarou and Zervas, 2014; Hsu and Sandford, 2007; Keeney, 2010; Linstone and Turoff, 1975; von der Gracht, 2012), several measures were considered to allow a more robust assessment of consensus (when reached):

- Agreement within two categories on a five-point Likert scale (>50%)[120];
- Kendall's coefficient of concordance in ranking questions[121];
- Measures of central tendency (mean and median[122]);
- Level of dispersion (low standard deviation [123] and low inter-quartile range, IQR[124]).

8.4.Results and discussion

This section analyses and discusses the Delphi results. The analysis begins with the debate regarding CE definition, moving on to expected scenarios in CE development for the next 20 years, especially concerning its main barriers and drivers. Innovation role throughout that agenda was also addressed, mainly regarding EI mechanisms (technological/non-technological) and EI targets (Oslo Manual taxonomy and integrative category- "Systemic EI"). Several concerns towards a CE implementation were also examined considering various stakeholders, namely socio-cultural factors and innovation by and from "consumers"; organisational strategies; and policy priorities. Initial findings reinforce the relevance of a systemic view in this field, pointing to important implications for the development of circular pathways.

[120] E.g. in Giannarou and Zervas (2014) and Keeney (2010).
[121] Main statistics for the ranking phase include the mean item ranking, share (%) of experts placing an item in the top half of their list, and Kendall's W (Schmidt, 1997). The Kendall's W is a non-parametric statistic test to measure agreement in ratings, ranging from 0 -no agreement- to 1 -complete agreement. Consensus was considered reached when W=>0.5 (Okoli and Pawlowski, 2004; Paré et al., 2013; Schmidt, 1997).
[122] Some authors (for instance see Murphy et al., 1998) recommended the median and interquartile range rather than the mean and standard deviation, because this measures are generally more robust (von der Gracht, 2012). As there is no consensus, both sets of measures were performed.
[123] Measures of central tendency are used to quantify the amount of variation or dispersion (Giannarou and Zervas, 2014). Standard deviation is a measure of dispersion of the mean. It intends to capture the average distance of each score from the mean, therefore it is normally examined with the mean (Gracht, 2008). Several authors considered a low standard deviation around 1.64, namely West and Cannon (1988) and Rogers and Lopez (2002); while others propose 1.5 (Christie and Barela, 2005; Giannarou and Zervas, 2014).
[124] IQR is a measure of statistical dispersion showing whether the responses are clustered or scattered across the range of possible responses. Smaller values (around 1) indicate agreement and larger ones least agreement (Culley, 2011; Giannarou and Zervas, 2014; Lee and King, 2009; von der Gracht, 2012).

8.4.1. CE's definition

Considering its potential in the sustainability transition debate, experts view CE as a *clearer and more tangible*, operational and helpful approach than others like "green economy", "cradle-to-cradle" or "green growth" (consensus of 57% in Round 2 – Question 2.1: Appendix 12). Experts have the highest level of agreement when defining CE as a *holistic* and *multidimensional approach* towards a paradigm change (consensus of 81% in Round 2 – Question 2.2: Appendix 12) and as a *business-friendly concept* "in the sustainability debate (consensus of 71% in Round 2 – Question 2.3: Appendix 12). These findings echo the perception of CE' momentum in the sustainability debate as a promising approach to improve "concreteness" in objective setting, enabling a more comprehensive action than sustainability (Kirchherr et al., 2017; Sauvé et al., 2016).

Despite the consensus on CE's definition (consensus of 52% in Round 2 – Question 1: Appendix 12) as "an approach compatible with economically viable sustainability by coordinating production, social systems and consumption habits into a production-usage closed circuit", respondents further emphasised the need to include in the definition some social and behavioural considerations lacking in previous characterisations (gap also identified in the literature see Murray et al., 2017; Washington, 2015). Merely closing loops is not considered enough: it is the entire congruence of a new techno-economic compact that matters. The improved definition that increased the consensus (consensus of 53% in Round 3 – Question 1: Appendix 12) reiterates CE as an approach to sustainable development (therefore focused on the conciliation of economic, social and environmental objectives), achieved through the reorganisation of production and social systems, into regenerative production-usage closed circuits, concentrated on resource and waste minimisation, design for efficiency, reuse, repair, and recycling.

8.4.2. CE's drivers and barriers

The development of CE in the next 20 years (First Round question B and then in Round 2 and 3 open question 1.1: Appendix 10 and Appendix 11) is emphasised as contingent on contextual factors, especially political and economic, and the overcoming of short-term barriers (e.g., prices not reflecting environmental damage in due time). Two very antagonist positions emerged in this regard: one stating that CE strategies will improve but never become mainstream; and another considering CE the best answer to sustainability issues. This dichotomy of answers shows a polarisation of opinions regarding CE, still considered too broad and problematic to define and circumscribe (Birat, 2015). Respondents underlined that the acceleration of CE transition in industry is dependent on the identification and exploitation of opportunities at company and inter-company level. But companies fail to see urgency or profit gains in taking advantage of existent recycling and reuse opportunities and prefer to follow the traditional pathway ("where risks are known and controlled") instead of innovating and trying new approaches. In this regard respondents stress what has been identified in the literature as the need to boost "integrative decision support tools to identify and tap potentials of CE transition scenarios" (Lieder and Rashid, 2016, p. 48). This relates to entrenched incumbent paradigms and lock-ins (Markard et al., 2012; Schulte, 2013), as well as the difficulty in reorganising production processes and product expectations (Kopnina, 2018).

Consumers are also considered unaware of CE products/services, their mind-sets and preferences only changing very slowly. This pattern is in line with the literature, which refers consumer's awareness as a major gap in CE implementation (EC, 2015b), and that points also to the preponderance of top-down policy measures limiting its implementation (i.e. consumers matter) (Kopnina, 2018).

When asked about drivers and barriers to CE (Table 45) experts stressed economic factors as main drivers and, at the same time, main barriers, i.e., a critical factor (Table 46 and Table 47 – from Question 3 and 4: Appendix 12). Displaying a low agreement (demonstrated by a low W), experts underlined high initial costs and market uncertainty as hampering transition, which is in line with the literature on this issue (Reh, 2013; Sanyé-Mengual et al., 2014). What is of special relevance is the importance given to socio-cultural factors as barriers, contrasting with most of the scholarly work that has been stressing technological factors as main barriers, namely technological thresholds (Geng et al., 2014; Yu et al., 2014), and technology gaps i.e. lag between invention and production (Gao et al., 2006; Kaenzig and Wüstenhagen, 2010; Pajunen et al., 2013; Vernay et al., 2013; Watkins et al., 2013). The same can be gathered regarding EI mechanisms where experts stressed that non-technological innovation is more important (Question 6: Appendix 12). As technological innovation is increasingly becoming incremental and posing implementation problems, even if it "enables change”, it is considered dependent on other non-technological factors, especially business model innovation, necessary to “drive and boost” CE (Geissdoerfer et al., 2017).

	Drivers	Barriers
Economic/ Financial/ Market	Seeking first-mover advantages; competitive advantages and costs reduction	High costs, uncertainty in returns and profits, asymmetric information
Technical	Available technologies (that enable resource optimisation, remanufacturing, reuse) and technical capabilities	Unavailability of cost efficient technology, lag between design and diffusion, deficient technical support and training
Institutional/ Regulatory	Legislation, environmental standards, and waste management directives	Misaligned incentives, deficient institutional and legal framework
Social/ Cultural	Social awareness to environmental questions, shifting consumer preferences (e.g. sharing and hoping systems)	Lack of awareness, rigid behaviours, resistance to change

Table 45 - Experts’ opinions on CE Drivers and barriers

Drivers Ranking	Mean		Median		Standard deviation		Inter-quartile range		Kendall's W
	Round 2	**Round 3**	**Round 2**	**Round 3**	**Round 2**	**Round 3**	**Round 2**	**Round 3**	**Round 3**
Economic/ Financial/ Market factors	1.4	1.7	1	1	0,7	1,1	1.0	1.0	0,33
Socio/Cultural factors	2,6	2,2	3	2	1,0	0,9	1.0	1.0	
Institutional/ Regulatory factors	2,9	2,7	3	3	1,0	0,9	2.0	1.0	
Technical factors	3,1	3,4	3	4	0,8	0,8	2.0	1.0	

Table 46 - CE drivers ranking (2nd round and 3rd round)
Note: Elaborations on the Delphi; applies to all tables and figures in the chapter from now on, unless otherwise stated

Barriers Ranking	Mean		Median		Standard deviation		Inter-quartile range		Kendall's W
	Round 2	**Round 3**	**Round 2**	**Round 3**	**Round 2**	**Round 3**	**Round 2**	**Round 3**	**Round 3**
Economic/ Financial/ Market factors	1,5	1,5	1	1			1.0	1.0	0,50
Socio/Cultural factors	2,3	2,2	2	2			1.0	1.0	
Institutional/ Regulatory factors	2,5	2,5	3	3			1.0	1.0	
Technical factors	3,6	3,8	4	4			0.0	0.0	

Table 47 - CE barriers ranking (2nd round and 3rd round)

8.4.3. Priorities towards a Circular Economy

8.4.3.1. Socio-cultural factors and innovation by and from "consumers"

The importance given to socio-cultural factors as limitations in a CE development is even more evident when observing social involvement in the practical application of that approach. Consumers are understood as not yet fully tuned in to the CE mind-set (First Round – Question I: Appendix 10). Conscious or "circular consumption" is considered difficult to attain, with social and economic impediments that stifle the impact of consumers choices (e.g. experts mention that circular products are normally more expensive, labels are not clear to the average costumer, and even time can be a problem, as significant search costs are involved when scrutinising purchasing decisions). This echoes findings stressing that neither business models, nor consumer preferences alone appear to be assisting in the development of a CE (Kirchherr et al., 2017).

Therefore, even if co-creation[125] is consensually identified as important in boosting circular business models (consensus of 57% in round 2 – Question 7: Appendix 12), experts refer consumers' actual behaviour disconnected from rationalised preferences ("what consumers say is not what they want, need or do"). Additionally, customers awareness and cultural acceptance of some of the most innovative components of CE business models, like "product service system", "performance based contracting", "product as a service", meaning provision of a service rather transfer of ownership, is still progressing slowly. As Planing (2015, p. 7) put it "consumers prefer ownership of a product, even if temporary usage is more economical".

What seems of further relevance is that, when asked regarding that same importance in 2030, the consensus level augmented to 76% (in Round 2 - Question 8: Appendix 12). These results clarify the other commentaries of the respondents, stressing that one of the biggest challenges is "making CE relevant to consumers". Change is considered as arriving mainly from the production side (company push and institutional frameworks). Consumer engagement is important in changing consumption and usage habits, but still weak in pushing regulatory frameworks and recognising the technical limits of circular strategies in certain contexts. There is consensus that the availability of

[125] Defined as "joint creation of value by the company and the customer." (Prahalad and Ramaswamy, 2004, p. 8)

information and the promotion of awareness are fundamental, for instance through the facilitation of consumer communities (Question 10.1: Appendix 12), and using social media and the web at large (Question 10.2: Appendix 12).

8.4.3.2. Organisational strategies

As for organisational strategies, investment in “circular” business models’ innovation is the most consensual focus point in Round 2 (consensus of 100% in Round 2, and in mean ranking in Round 3 – Question 11.3: Appendix 12). The development of networks of cooperation with other enterprises and the promotion of internal communication between departments namely innovation, design, and engineering are other of the top 3 most important strategies identified (Question 11.1 and 11.5: Appendix 12).

But the angle that keeps getting reinforced in our results is the indispensability of a *systemic* approach towards a CE, involving a *plurality* of actors, namely policymakers and businesses, in *coordinated* policies and regulations. In the literature, that same assumption appears, especially in the EU’s communications which emphasise that CE requires systemic innovation, “technological and institutional changes, both at the level of markets and in terms of policies addressing mind-sets and infrastructures” (EC, 2015c, p. 12). In fact, not all EI has the same impact on the development of a CE. The consensus is on “systemic EI”[126] (Table 48 from Question 5: Appendix 12) as an approach that encompasses the whole value chain and engages all actors involved as “the kind of joined-up thinking that is required to make progress towards a true CE”. This is in line with the EU’s vision of a CE contingent “on adopting a systemic approach to eco-innovation that encompasses value and supply chains in their entirety and engages all actors involved in such chains” (EC, 2015b, p. 73). As for agency, respondents stressed that systemic innovations are the concern of policymakers, industry regulators and groups of businesses such as industry trade groups and business districts. Individual businesses are less likely to consider and invest time, money and energy in systemic innovations due to trust and coordination issues, asymmetrical information, the possibility of others free riding on their investment, and uncertainty on how to appropriate the fruits of research.

[126] The OECD Oslo Manual taxonomy was used (OECD, 2005), but a integrative category- "Systemic EI" - was added.

EI Types	Mean		Median		Standard deviation		Inter-quartile range		Kendall's W
	Round 2	**Round 3**	**Round 2**	**Round 3**	**Round 2**	**Round 3**	**Round 2**	**Round 3**	**Round 3**
Systemic eco-innovation	4.6	1,2	5	1	0.51	0,8	1.0	0.0	0,50
Good or service eco-innovation	3.8	2,4	4	2	0.68	0,9	0.0	1.0	
Process eco-innovation	3.7	3,2	4	3	0.66	1,0	1.0	1.0	
Organisational eco-innovation	3.6	3,6	4	4	0.98	0,8	1.0	1.0	
Marketing eco-innovation	3.5	4,6	4	5	0.98	0,8	1.0	0.0	

Table 48 - EI types – 2nd and 3rd Round

8.4.3.3. Policy priorities

One of the inputs of the first Delphi round was the expert's crosscutting consideration of the importance of a contextual support in the dissemination of CE. Systemic interventions were emphasised as grounded on policies and especially on innovation policy, using both supply and demand-side instruments (Table 49); this is shown by the experts' converging in Round 2 on all policy instruments tested in the Delphi (Table 50 from Question 12:Appendix 12).

In Round 3 experts were asked to rank those policy instruments. On the supply-side, instruments focused on enhancing framework conditions for innovation, such as "Strengthen policies on waste avoidance to encourage innovation - new product designs, and use of recycled or reused materials", were consensually considered the most important. Experts stressed the need to integrate existent initiatives and regulatory frameworks in a more coherent strategic roadmap, to avoid contradictory incentives, improve cooperation and networking in the system. On the demand-side, instruments focused on fostering demand for reflexive and responsive innovation. For instance, an issue such as "Enhance demand (support and encourage actors' awareness and increase social participation)", was also deemed critical, in addition to the encouragement of "circular" procurement (also put on the top half of the list, even if responses were scattered - the standard deviation and the IQR were very high) (Table 50). Procurement has, in fact, been stressed as an instrument to help readjust production and consumption trends towards more circular pathways, at the same time boosting innovation and goods/services diversification (Cayolla Trindade et al., 2018; Witjes and Lozano, 2016). A *circular procurement strategy* may, therefore, be helpful in the realigning of suppliers and markets to encourage the take-off or development of more circular goods and services (Cayolla Trindade et al., 2018).

Innovation policy	Description	Instruments and goals	Examples tested in Delphi
Supply-side instruments	Instruments seeking to induce innovation, addressing market and system failures that lead to underinvestment in innovation, like: lack of connectivity; institutional rigidity; constrains in the access to information or other resources	Measures to increase private investment in R&D and innovation as tax incentives and subsidies Improve access to finance (facilitate R&D and innovation investment) Skills development, improving access to expertise Cluster policies, network policies and support for R&D cooperation	Dedicated tax policy Develop financial tools to support circular economy eco-innovations Private and public investment in R&D and base science to support circularity Promote science education and training Encourage industry sectors to deliver specific transition plans Strengthen policies on waste avoidance to encourage innovation - new product designs, and use of recycled or reused materials
Demand-side instruments	Instruments seeking to influence potential users to demand and apply innovation.	Public procurement measures to boost commitment and awareness Support private demand Framework conditions and market creating mechanisms.	Encourage “circular” procurement Enhance demand (support and encourage actors’ awareness and increase social participation) Providing an institutional regulatory framework

Table 49 - Innovation policy instruments and goals
Note: Based on Edler et al. (2013, 2016), own elaborations

Other areas lacking consensus like “Private and public investment in R&D and base science to support circularity”, “Develop financial tools to support circular economy eco-innovations”, “Encourage industry sectors to deliver specific transition plans”, “Private and public investment in R&D and base science to support circularity”, “Promote science education and training” and “Providing an institutional regulatory framework”, may be attributed to a polarisation of experts in two categories: the ones considering that policy goals should focus on promoting and facilitating market integration of pro-CE innovations, and the ones stressing the need for public investment and initiatives in the development of infrastructural conditions to enhance CE application. This lack of consensus does not necessarily mean that these policy instruments are inappropriate, but may point to difficulties in both their implementation and the identification of the right "policy mix" (Edler et al., 2016; Veugelers, 2012).

	% Likert Scale 4-5 Consensus = > 51%)		Standard deviation		Median		Mean		% of respondents placing each item in the top half of their list		IIQ (Q3-Q1		Kendell's W
	R 2	**R 3**	**R 2**	**R 3**	**R 2**	**R 3**	**R 2**	**R 3**	**R 2**	**R 3**	**R 2**	**R3**	**R 3**
Dedicated tax policy	61.90%		1.16	**2.24**	4	8	3.57	7.18		17.65%	1.00	1.00	0.50
Develop financial tools to support circular economy eco-innovations	57.14%		0.98	**1.82**	4	7	3.57	5.94		35.29%	1.00	**2.00**	
Encourage industry sectors to deliver specific transition plans	57.14%		1.12	**1.93**	4	9	3.38	7.71		11.76%	1.00	**2.00**	
Encourage "circular" procurement	66.67%		0.84	**2.67**	4	1	4.00	2.88		82.35%	**2.00**	**3.00**	
Enhance demand (support and encourage actors' awareness and increase social participation)	80.95%		0.59	1.58	4	3	3.95	3.12		94.12%	0.00	1.00	
Private and public investment in R&D and base science to support circularity	76.19%		0.77	**1.71**	4	4	3.90	4.24		76.47%	0.00	**2.00**	
Promote science education and training	71.43%		0.75	1.59	4	6	3.81	5.82		41.18%	1.00	**3.00**	
Providing an institutional regulatory framework	66.67%		1.01	**1.95**	4	6	3.71	5.76		41.18%	1.00	**2.00**	
Strengthen policies on waste avoidance to encourage innovation - new product designs, and use of recycled or reused materials	80.95%		0.89	1.06	4	2	4.00	2.35		100.00%	1.00	1.00	

Table 50 - Policy instruments towards CE – 2nd and 3rd Round
Note: Bold when consensus was not reached

Indeed, when analysing experts' comments in this section a new combination between supply and demand-side instruments seems urgent. At the same time that experts underscore the need for institutional framing conditions (demand-side), they stress the importance of regulatory frameworks, tax breaks, nudges to boost private and public investment in R&D and other supply-side incentives.

8.4.4. Discussion of results and implications for circular pathways

The above set of observations, gathered throughout the Delphi study, can help to structure the debate regarding possible priorities and measures with the potential to positively act upon the transition to a CE. This can even be more informative if main Delphi findings are put side-by-side with conclusions emerging from systematic literature reviews (Part I). Table 51 synthesises the main contrasts, considering that a better understanding of these diverse perspectives is needed in order to better tailor strategies and policy implementation.

Overall, a convergence was found among the experts on the CE definition, as *an approach on sustainable development, committed to the conciliation of economic, social and environmental objectives, achieved through the reorganisation of production and social systems, into regenerative production-usage closed circuits, concentrated on resource and waste minimisation, designed for efficiency, reuse, repair, and recycling*. This definition is not altogether different from other CE definitions from the literature, even if it further stresses the social dimension, previously vague, pointing perhaps to CE's "coming of age" as a (deep and strong) sustainability approach. Despite looking still a bit far from the mainstream, the momentum that CE now enjoys may be capitalised to improve "concreteness" in pro-sustainability policy definition, profiting from CE's characterisation as a more tangible, and operational concept and from EI as a transition vehicle.

Regarding barriers and drivers to CE, both the literature, as well as the practitioners consulted in the Delphi stress Economical/Financial/Market factors. These convergence points to the critical importance of overcoming hindrances related with high initial costs, market uncertainty, as well as inertia, lock-ins, and path-dependencies, which characterise prevailing systems. But when divergences are considered concerning barriers to a CE, findings are also noteworthy. A question that stands out is why the literature underscores technological barriers, and “practitioners” consensually find them inconsequential, stressing instead socio/cultural issues? This mismatch may be related with literature bias towards base science and technology as a transition pathway. It can also be practitioners’ preconceptions about limited market acceptance of a CE and inherent obstacles to frontrunners in niche areas as the CE still is.

Another point relates with governmental “coordination role” and its enabling of “framework conditions” in CE implementation. Delphi experts, same as the literature, put weight on public policy measures (e.g. legal frameworks, taxes, incentives, infrastructure development) addressing market failures, technological limitations and socio/cultural difficulties. Specifically regarding regulatory frameworks, the experts considered CE as able to benefit from the integration of the already existent multiplicity of initiatives in a more coherent strategic roadmap, in order to avoid mismatches and contradictory incentives. A parallel can be found in the EU, for instance, where arguably current fiscal policies continue to support a take-make-dispose economy (Sans et al., 2017), maintaining subsidies contributing to pollution and conciliating conflicting inducements (e.g. promotion of product efficiency and, at the same time, stimuli for the replacement of old appliances).

However, these framing conditions are not only of a regulatory nature, they also concern the provision of infrastructures and human capital (technical support, aid in training, demonstration of best practices), and the diffusion of CE related information for both enterprises and civil society (campaigns to promote CE and support market awareness, as well as the penetration of innovative projects - e.g. public procurement). That is, promoting cooperation between actors, changing customer preferences to, and business action towards, CE models. This finding is important because it points to the usefulness of rethinking and redirecting innovation policy design instruments, both the ones inducing innovation and limiting market and system failures (that lead to underinvestment and lack of connectivity in innovation), but also instruments influencing potential users, towards “circular” mind-sets. This directly links to the consensus found around the importance of *systemic action* underlining a need for a clear strategy for CE implementation. Not isolated initiatives, but rather a broader effort to align policies at several levels and areas, linking bottom-up measures to already existent top-down policies.

In this regard, inter-firm relationships in the innovation process was emphasised, especially the development of networks between firms along the value chain. This can enable the gathering of insights on the most important CE opportunities and barriers in each sector, but also endow a sectoral circular alignment with the potential to add critical mass and propagate perceptions of CE's possibilities and advantages, increasing chances of strategic emulation.

As for consumers, their awareness and interest in CE goods and services is still found stifled by price considerations, the availability of clear information regarding effective "circularity" of the good/service, and credibility regarding "greenwashing" rhetoric. These kinds of barriers are particularly problematic to overcome considering that is very difficult to change "minds and habits". At the same time these cultural aspects deeply influence market dynamics (as one of the Delphi respondents pointed "if the demand increased enterprises would shift to CE products and services as to make the most profit"). This is still a gap of policy intervention as priorities are more focused on technological barriers underestimating other economic and socio-cultural non-technological factors, which appeared emphasised in this Delphi study. Policies should be redirected to these issues, focusing for instance on information provision and on the improvement of existent labelling and certification systems. Also, financial instruments that take into consideration non-technological innovation, like business model innovation, seem somewhat overlooked even if consensually found important by the Delphi expert panel for boosting a wider range of CE projects and thus fostering a faster transition.

While this type of exercises allows for the discovery of relevant information for fine-tuning public policies, derived from those with "boots on the ground" in these matters, naturally the "policy mix" must be defined country-by-country/sector-by-sector to take advantage of the variety of opportunities and challenges in transitioning towards a CE.

	Literature	Practitioners (Delphi)
CE definition	Several definitions focused on closing the loop, limiting inputs, reconceptualising systems, and reconfiguring waste	Stress on CE as an approach on sustainable development (therefore focused on the conciliation of economic, social and environmental objectives)
Barriers to CE	Predominance of Technical and Economical/Financial/Market. Therefore "Hard" Barriers	Predominance of Economical/Financial/Market and Socio/Cultural Barriers. Therefore a mix of Hard and Soft barriers
Drivers to CE	Predominance of Economical/Financial/Market and Institutional/Regulatory Drivers. Therefore "Soft" Drivers	Predominance of Economical/Financial/Market and Socio/Cultural Drivers. Therefore a mix of Hard and Soft barriers
EI Target	CE seems to be contingent on a process based on cooperation and multi-actor "systemic" integration, with EI emerging as a pathway for achieving that.	Consensus on systemic EI as an approach that encompasses the whole value chain and engages all actors involved as "the kind of joined-up thinking that is required to make progress towards a true CE
EI Mechanisms	Technological innovation considered the most important	Non-technological innovation considered as the most important
Priorities towards a Circular Economy: Governmental "coordination Role"	Government role is key regarding the creation of a CE, ensuring adequate regulatory frameworks, and encouraging the awareness of actors and social participation.	Crosscutting consideration by the experts of the importance of a contextual support in the dissemination of CE. Systemic interventions were emphasised as grounded on policy intervention
Priorities towards a Circular Economy: Enterprises/ Industries	Challenges in boosting cooperation between enterprises and between enterprises and public actors, promoting symbiotic links, addressing technical issues and overcoming institutional barriers The promotion of new business models and the benefits of a CE is still perceived as lacking Corporate world seems to be slow in adjusting its own business models and environmental considerations to CE practices	Respondents underlined that companies fail to see urgency or profit gains in taking advantage of existent recycling and reuse opportunities and prefer to follow the traditional pathway (where risks are known and controlled) instead of innovating and trying new approaches. This relates with entrenched incumbent paradigms and lock-ins
Priorities towards a Circular Economy: Consumers	Consumers considered still mostly unaware of the choices available. The lack of transparency and credibility coming from dissatisfaction with empty greenwashing rhetoric also hampers the development of "green markets" and customers' willingness to pay for "green" goods and services Role of consumers as innovative agents is not much addressed	Consumers are understood as not yet fully tuned in to the CE mind-set. This is stressed as an important barrier. Consumer engagement is important in changing consumption and usage habits, but it is considered weak in pushing regulatory frameworks and recognising the technical limits of circular strategies in certain contexts.

Table 51 - Comparing literature with Delphi findings on CE

Note: Inspired on Delphi findings and literature reviews (de Jesus et al., 2018; de Jesus and Mendonça, 2018; Geissdoerfer et al., 2017; Homrich et al., 2018; Kirchherr et al., 2017; Korhonen et al., 2018a; Murray et al., 2017)

8.5.Main Conclusions

Placing itself within the deep transition debate, this chapter intended to provide insights on CE by addressing socio-cultural, organisational and policy priorities in encouraging CE. In the consideration that in a constantly changing and uncertain world foresight matters, this analysis used a Delphi study, a method particularly suited for ascertaining future directions in areas where there is incomplete and uncertain knowledge.

This enabled a generative conversation around CE's definition and its further developments. Experts' answers suggest that the next 20 years will be fundamental for CE's establishment within the sustainability debate, its implementation being dependent on overcoming short term barriers constraining its further development, economic, but also of a socio-cultural nature, having to do with the ideology of economic growth, established industrial lobbies and policy intervention that is sometimes uncritical of the way these lobbies and industrial operations conduct their businesses. CE can still be subverted and linked to ultimately unsustainable business-as-usual models, being susceptible to misappropriations and inconsistencies that must be taken into consideration. Some companies associated with "circular " practices will just keep focusing on minimising damage, recycling and eco-efficiency, with CE advertised as a "new engine of growth" rather than promoting transformational (i.e. paradigm-mutating) change. Nevertheless, this Delphi study highlighted that the implementation of a true CE is within reach, requiring systemic action grounded on explicit policies (private and public investment in R&D), focusing on system and product redesign, the cooperation between the various actors, particularly amid enterprises, and the development of innovative "circular" business models contextualised by an encouraging institutional and regulatory framework and an informed and active society.

Even using transparent methodological choices, the Delphi method inherent constraints are the main limitations of this work. These underline the necessity of critical reflection about the findings, along with further empirical research. Regarding new research avenues, even if CE has already been considerably studied, several knowledge gaps can be further addressed, concerning stakeholder's difference of understanding regarding CE implementation; and limitations on CE assessment. Both these issues are important to governmental intervention in order to avoid biased policies, failing in its overall objectives.

CHAPTER 9

BRINGING IT ALL TOGETHER: RESEARCH OUTCOMES AND CONCLUSIONS

Scientific evidence of anthropogenic degradation of global ecosystems, as well as the consideration of the inherent limits of natural resources, is suggesting the inadequacy of the prevailing resource/energy complex (OECD, 2012). As several planetary thresholds have been crossed, the risk of irreversible environmental change is nowadays a major issue, capable of making the headlines, often for weeks in a row, when extreme events like heatwaves, draughts, hurricanes, floods, and snowstorms strike, sometimes in succession (Rockström et al., 2009; Smil, 2008). To keep relying on ever growing input flows to feed civilised existence is impossible without changing the very foundations of the prevailing societal organisation (Smil, 2012).

This research adds to the debate using an innovation studies perspective. New generation technology has the potential to tackle environmental degradation, mirroring the way the old industrial-polluting complex ultimately promoted it. At the same time, environment-friendly productive knowledge may positively alter the fickle balance between economic development, international competitiveness, and the natural capital. The starting point was that assessing pro-CE EI dynamics could cast some light into the transition towards a CE and a new socio-techno-economic paradigm for environmental sustainability. This chapter envisions to "make sense" of main conclusions, especially discussing the research questions and how far can they be answered through the lens of the integrated findings presented through Chapters 2 to 8. First, in the closing of this research it seemed the time to, in an informed and up-to-date fashion, ponder on the nature of a CE itself, considering its future development and implementation (section 9.1). This is followed by an integrated debate about main findings and answers to research questions (section 9.2) and main policy implications from those findings (section 9.3). At this point section 9.4 discusses opportunities and challenges for Portugal (a transversal case study in the research). Considering that sustainability is inherently a global issue, some reflections also seem relevant concerning countries disparities and gaps of knowledge (Section 9.5). Finally, section 9.6 concludes by making an overall reflexion regarding the research approach, highlighting main contributions, underlining limitations and pointing out further research pathways.

9.1. Circular Economy – Potential, misconceptions and limitations

One of the main implicit issues, addressed throughout the research, focuses on the nature of a CE itself, and its advantages within sustainability transition approaches. CE was interpreted as an operative approach with benefits for advancing the transition, although several limitations do exist that have to be considered. Taking stock of the work done and the overall findings of this research, this seems to be the right moment to discuss those issues and identify the potential, as well as some dangers for CE's future development and implementation.

As CE main ideas are arguably timely and necessary, the conceptual challenge is still underway. As Kirchherr et al. (2017) stressed, the CE approach will not deliver fundamental change if subverted definitions start leading its implementation and development; even if it is difficult to limit misappropriations and ambivalences (Sauvé et al., 2016). On one hand, this is an approach addressed by several schools of thought albeit with conceptual discussions still in its early stages (Korhonen et al., 2018b). On the other hand, it emerged not only in academia, but also deeply associated with policymaking. Therefore, its definition has been addressed within these specific *foci* and disciplinary epistemologies (Reike et al., 2018).

Beliefs regarding CE's value in delivering sustainability remain divided, between some more critic antagonists to the concept and its meaning (Skene, 2017), and others aligned with the identified potential that the approach seems to enable (Kalmykova et al., 2017). Although 2017 saw a rise in the number of scientific articles published concerning this subject in main databases, like Scopus and WOS (which more than doubled), the promises that CE may hold to the sustainable development efforts are dependent on a clear and inclusive definition. This was a concern of this research even if this discussion is far from being closed. What seems important to stress is the necessity to avoid emptying "CE" of meaning. This conceptual restlessness must be consolidated to ease potential progress in this field.

Additionally, several questions regarding the "revolutionary" character of CE must be underlined. A CE has been described as distant from radical change (Hobson and Lynch, 2016; Skene, 2017), echoing earlier ecological modernisation arguments conciliating environment and economy on the road to sustainability (Mol and Spaargaren, 2000). Nevertheless, a systemic understanding of a CE may not, and should not, be replaced by a simplistic reliance on "green" technologies (Hobson and Lynch, 2016). Citing Murray et al. (2017, p. 376) "a bamboo chopstick would be better than a highly specialised plastic fork, as it could easily be recycled and would only briefly be removed from the Biosphere". Some other authors even stress that this overemphasis on technology may be one of the reasons behind the slow advancements in this approach (Blomsma and Brennan, 2017; Reike et al., 2018). But this is also not the same as saying that technology is not important. As this research presented, there are already several examples of both soft and hard innovations likely to impact on a CE. The main issue here seems to be the development of integrative strategies towards "circularity".

This directly links to the "speed of change". Even if several countries are already moving in a CE direction, research shows that this is still happening at a slow pace. Granted, isolated efforts are being made, but systematic strategies for the CE are few, mainly circumscribed to North Europe countries (Government of Netherlands, 2016; State of Green, 2016; Taranic et al., 2016), and investment too low (SYSTEMIQ and EMF, 2017).

The social dimension of the CE is another issue. As main definitions and implementation strategies of CE focus on the production and service systems, CE's social dimension still seems overlooked (Geissdoerfer et al., 2017). The depoliticisation of the role of citizens (or better of consumers/users), which was also stressed throughout this research, seems to hamper the transformative potential of a CE. Though thought to be of relevance in the future, it is important to emphasize that an inability to address sustainable consumption and sustainable lifestyles now, will inevitably impact down the line further implementation and widespread of a CE (Hobson and Lynch, 2016).

That being said, the potential within a CE must also be argued. CE proposes an approach that "enables the development of contractual agreements between the users and providers of products and services that can better align incentives and lead to more eco-efficient uses of resources." (Sauvé et al., 2016, p. 55). The evolving definitional question must not be used as an excuse to stop addressing the efforts of development and implementation of the approach (Korhonen et al., 2018a). If anything, the conceptual restlessness and increasing awareness concerning CE stresses its potential and its evolving dynamics. CE's connection with EI further highlights the contingency of transformation on a process based on systemic integration of both technological and non-technological nature, building on cooperation and multi-actor "networking" and on the redirection of "innovation systems" towards CE-inducing productive and social practices. If sustainability's broad objectives and top-down approach limit the delineation of a pathway to achieve transition (Kopnina, 2018; Sauvé et al., 2016), CE's more down-to-earth perspective favours implementation and the identification of policy priorities. CE is what some authors called an "essentially contested concept". Other contested concepts are the ones of "democracy", "sustainable development" and "sustainability" (Korhonen et al., 2018a; O'Riordan, 1993). That is, valuable societal goals from the point of view of national and international polities and large economic institutions of indisputable relevance, even if the road there may seem challenging.

9.2."Making sense" of main findings

While the CE approach provided context and a common thread to the present research, innovation occupied central stage. Realising the potential of transition-friendly innovation in helping actors to better achieve their circularity efforts was the basis of this project. In the realigning of innovation activities towards more sustainable paths, which transformations are most instrumental? In particular, what is the role of EI in the operationalisation of a CE? Within the sustainability debate, and using an innovation studies perspective, this research aimed to explore how innovation systems could be redirected and encouraged towards a CE. As this is a tremendously broad question, this analysis was sub-divided in three research questions:

- **RQ 1**: How are CE and EI characterised and how the concepts are related (what are the relations between the different dimensions of EI and the various levels of a CE?)
- **RQ 2**: How can indicators of socio-techno-economic change, i.e. CE-inducing EI, be operationalised? How can innovation systems circularity be assessed?
- **RQ 3**: Which are the main socio-cultural, organisational, and policy implications of the CE-EI relation for redirecting innovation systems?

In the research **"PART I"** CE and EI literature review provided the reflective analytic basis and conceptual discussion needed in the development of an integrated framework to understand the relation between CE and EI, in order to respond to **RQ1**. The main focus was on the conceptual definition of both and further discussion of their linkages, establishing the relationship between the different dimensions of EI by the various levels of a CE and distinguishing between *harder* and *softer* factors in the transition towards a CE.

Regarding the overlap between the EI and CE concepts, findings point out that CE and EI definitions are still "under construction", with latitude for further refinements. Nevertheless, as the field of CE would really benefit from a common terminology, working definitions were advanced. CE was defined as: *a multidimensional (macro, meso and micro), dynamic, integrative approach, promoting a reformed socio-technical template for carrying out economic development, in an environmentally sustainable way, by re-matching, re-balancing and re-wiring industrial processes and consumption habits into a new production-usage closed-loop system.*

Integrating a set of strategies ("input minimisation and efficient use of regenerative resources"; "life cycle extension and systems reconceptualization including facilitate maintenance; increase traceability for reverse logistics; the development of repair, reconditioning and remanufacturing options; the improvement of materials recycling; automation and digital supports to new business models - from products to services, performance savings, sharing and leasing, etc.)"; "output reduction, valorisation and waste minimisation") CE was understood as a form of clean congruence, i.e. a state of compatibility between technological and socio-institutional sub-systems that overcome the unresolved mismatches of the take-make-dispose economy paradigm.

As for EI, it is plausible that ("transformative") innovation may now be the vehicle for triggering a new, "green" socio-techno-economic system based on the concept of the CE. EI, understood as a systemic problem-solving pathway, was therefore defined as technological and non-technological *new or improved socio-technical solutions that preserve resources, mitigate environmental degradation and/or allow recovery of value from substances already in use in the economy*.

The conceptual definition of both notions urged a deeper dive into the key implications of the EI/CE connections. A framework to outline broad influential dimensions of EI within CE levels was proposed, using a corpus of specialised academic literature to provide supportive evidence, whilst distilling practical insights. The research emphasised that the relationship between CE and the notion of innovation is still not obvious, but stressed the CE as an integrative multi-actor approach in which EI could be a (technological and non-technological based) process in the transition towards a new socio-techno-economic "congruence". That is, current EI-CE research pointed to pockets of what was called generally as "clean congruence" at the macro-level, as “green collective innovation” at the meso level and “dynamic CE business models” at the micro level. At a macro level, a systemic approach to change, addressing the societal and contextual settings was highlighted as crucial. At this level, EI was understood as a new avenue for introducing systemic novelty within an integrated vision of society, economy and environment based on incremental redesign and the modification of existing systems, spanning different sectors and value chains. At the meso level, the CE approach was considered to be contingent on “green collective innovation”. That is, innovation that is based on multi-actor and multi-expertise comprehensive technological and non-technological (i.e. organisational and process) change. At a micro level, specific actors’ capabilities and involvement in CE implies a greater emphasis on new products, servicing, resource pooling and marketing concepts, with EI as a tool to empower “dynamic CE business models” from actions of cleaner production (in energy and materials efficiency) to the development of new, more circular models (i.e. service-based user-producer relationships).

The key implications of the EI/CE connections lead us to further coordinate available, but fragmented findings, regarding how “transformative innovation” could foster this transition while removing obstacles to sustainability. Adding non-academic literature to the previously analysed academic corpus, a framework for analysis regarding soft and hard factors was defined. The CE was found to be driven particularly by “soft” (i.e. social, regulatory or institutional) factors. At the same time, “hard” barriers, related to the availability of technical solutions and financial factors, can hamper the expansion of the CE. Nevertheless, even when CE solutions are already technically feasible, their practical implementation is often limited by social, economic and market limitations. If CE developments can already be stated as having a global geographical dispersion, its understanding and implementation is far from uniform (as it is further discussed in section 9.5). A key conclusion is that the innovation system’s lens should not be lost when considering the transition towards a CE.

Nevertheless, despite the literature addressing EI’s governance and policy, a knowledge gap is still apparent on assessing convergence to circularity, as well as the lack of a comprehensive discussion concerning CE empirical indicators. Hence, in order to address **RQ 2** it was necessary to explore how pro-CE EI could be assessed. Monitoring innovation systems dynamics, with a particular emphasis on their “circular” activities, enabled a glimpse on CE implementation and also supported the identification of policy implications. This research's **"PART II"** was focused on that objective. As available indicators fall short in assessing EI circular development, an "EI circularity assessment compass" was proposed. To appreciate the dynamics and inertia of the CE, the structural components of an innovation system were used as a "focusing device" (context, actors and networks), via the dichotomy between "harder" innovation proxies (patents) and underexploited non-technological, more "softer" ones (trademarks).

This work sought to identify possible CE and EI indicators and their limitations. It was concluded that even if some efforts to develop and adapt indicators to CE specificities are underway, monitoring and assessing it still remains a challenge, especially when the focus is on "CE-friendly" innovation. In that regard, innovation indicators "patents" and "trademarks" were identified as potential proxies in the assessment of CE dynamics as those indicators combine *scalability* (i.e. can be aggregated to cover several levels of analysis – sectors/countries/etc.); *multidimensionality* (cover several areas, i.e. are not narrowly defined); and *modularity* (may be combined with other indicators).

The objective was to define an empirical approach for studying (eco)-innovation systems in the development of a CE and proxies that could be tested in specific cases. Consequently, first, patents ability to measure and monitor "harder" EI that facilitate or induce the emergence of a CE was discussed, using the EPO's Y02 patent applications by Portuguese innovators for a period of 25 years as a proof-of-concept. Applying CE characteristics previously identified in the academic literature and using a participatory approach to validate its application to the patents, the research enabled a way to detect, classify and appraise patents, not only "green", but also pointing to CE characteristics. In the analysis of the Portuguese innovation system, uneven CE dynamics were uncovered (that is, signs of effective transformation on the supply-side but rather irregular) and structural issues identified (systemic failures in terms of actors and networks).

Secondly, since transition is about more than radical, technological and manufacturing-based innovation, "softer" indicators, sensible to incremental, service-oriented, SME-intensive innovation were explored. Non-traditional innovation indicators potential for measuring and monitor the "deep transition" towards a CE were analysed and trademarks argued as a meaningful complementary indicator of pro-circular “softer” innovation. A proof-of-concept empirical application of this approach was carried out on the basis of an original and purposely-build dataset, using Portugal’s case, adding to the previously use of patents as a “harder” proxy.

Trademark analysis pointed to trends difficult to capture by other indicators, signalling an uneven progress, vulnerable to macroeconomic dynamics, with a focus on traditional “low-tech” goods, but an increase in services. Also, a reinforcement of the entrepreneurship structures in CE business models in Portugal may be perceived, albeit focused on small agents and start-ups.

Both trademarks and patents enabled and complemented the assessment of different parts of the innovation system. This analysis allowed the testing of empirical indicators, but also some considerations regarding innovation systems “alignment” towards “circularity”. Overall findings and insights on the Portuguese innovation system’s “circularity” will be further debated in section 9.4.

After a first part of a more conceptual and theoretical nature, and a second part engaged on an empirical debate regarding proxies and indicators of pro CE EI, **“PART III”** intended to gather insights from institutional sectors (public, business, academic actors, as well as NGOs) regarding the CE approach and its key priorities, implications and discussing concluding remarks. Even if the answer to the **RQ 3** benefits from findings throughout the research, this third and final part broadened its response.

A three-round Delphi study, involving practitioners and researchers, shed light on socio-cultural, organisational and policy priorities in encouraging CE, allowing a debate concerning future directions and implications. This reiterated previous findings regarding difficulties in defining CE and possible distortions or misappropriations of the approach, which may limit its development in the next 20 years as a sustainability school of thought (also discussed in section 9.1). As such, improving the CE’s definition became of policy interest.

Transition to a CE was also underlined as contingent on a transformative process based on a systemic approach to CE-friendly EI. This highlighted the need for a clear strategy, not isolated initiatives, for pro-CE EI, rooted in coordinated policies and regulations, at several levels, using both supply and demand-side, as well as contextual instruments. Consequently, measures to limit inertia and lock-ins should focus on overcoming not only technological barriers, but considering non-technological innovation as well. The required systemic action was identified as grounded on explicit innovation policies. Those would benefit from integrating system and product redesign, cooperation between various actors, the development of innovative “circular” business models contextualised by an encouraging institutional and regulatory framework, and an informed and active society. An appropriate institutional framing is especially mentioned as essential, comprehending conducive regulatory frameworks, the provision of infrastructures/ human capital, and an active promotion of social "sensitivity" and awareness. Overall, this exercise consolidated major insights and relevant information to contribute to fine-tuning public policies towards a CE.

Table 52 synthesizes main findings and implications of this research which enabled the following discussion regarding possible public policy measures (section 9.3), general opportunities presented to countries (specifically looking into Portugal – section 9.4) and the relevance of this subject within the globalisation studies agenda (section 9.5).

	Findings	Implications
Macro	- CE and EI definitions are still "under construction" with latitude to further refinements. CE has been gaining relevance as an operational approach in the past years	- Field would benefit from a common terminology (improve CE definition became of policy interest)
	- Government and Policymakers are essential in providing conditions to prompt CE, especially in the beginning of the transition phase, setting targets, coordinating different initiatives, enacting appropriate regulations, i.e. directing socio-techno-economic activities towards circularity - Established legislation is also an important barrier, existing legislation limiting CE opportunities need to improve regulatory procedures	- Public agencies have a crucial role in planning, providing institutional standards and guidance (infrastructures provision/conducive legal system/ increasing social awareness/ framing context). - Need for further synchronising of environmental policy and science, technology, innovation and entrepreneurship agendas - The definition of public policies for the implementation and widespread of a CE should not overlook a more demand side/ social perspective focused on sustainable consumption and sustainable lifestyles
	- Boosted by global trends related to resource volatility and ever more stringent regulatory frameworks, the CE appears nevertheless hampered by technical and institutional factors. - EI mechanisms focus on the self-reinforcing combinations of socio-technological coalescing changes (i.e. "clean congruence") that allow transition to a CE to take place. - CE contingent "on adopting a systemic approach to EI that encompasses value and supply chains in their entirety and engages all actors involved in such chains	- A broad transformation is seen as contingent on more than just S&T; i.e. a transformative change is based on a systemic approach to CE-friendly EI - Pro-CE innovation policy is to provide R&D support, but should also facilitate peer-to-peer information exchange. - Promote systemic innovations is mainly a concern of policymakers, industry regulators and groups of businesses such as industry trade groups and business districts. Individual businesses are less likely to consider and invest time, money and energy in systemic innovations due to trust and coordination issues, asymmetrical information, the possibility of others free riding on their investment, and uncertainty on to how to appropriate the fruits of research - Critical considerations regarding the "goodness" of innovation must guide the integral analysis of the process of transition. Innovation is not enough. Systemic, transformative, and effectively sustainable innovation is the pre-requisite for sustainability
	- A deeper understanding of the connections between the CE and EI is still elusive, requiring more empirical methods for assessing and measuring their mutual influence at several levels - Several indicators used to assess CE lack coherence and overlook some of CE's specificities. There is also an absence of "CE-friendly" innovation indicators.	- Due to the difficulty to monitor such a multidimensional reality, assessment of CE implementation and circular activities implies a need for combining several different indicators to better track trends - Patents and trademarks can be interesting pro CE EI proxies. Portugal as a case study presents an innovation system with uneven dynamics regarding CE (that is, signs of effective transformation on the supply-side but rather irregular) and structural issues (systemic failures in terms of actors and networks) both in patents as in trademark indicators

Meso	- CE as an integrative multi-actor approach points to the importance of networks for building capacity; increasing cooperation in research and investment; sharing materials and by-products, and managing common utilities and infrastructures	- Strengthened cooperation between actors and resulting synergies limit exposure to resource price volatility, reducing costs and minimising the use of non-recyclable materials. - Importance of explicit public policies and new ways of streamlining cooperation between the public and private sectors.
	- Innovativeness for circularity is a distributed and systemic process, where the potential for synergies within value chains and territories is ripe.	- Promoting the cooperation and interrelation of geographically close companies and organisations is considered to be an effective way of achieving a more circular system, with better use of energy, materials and resources. - EI as a facilitator of systemic integration enables new ways of "green collective innovation" such as sharing services and other schemes for maximising the value of common resources, which in turn provides new ways of promoting cooperation.
Micro	- The replacement of the "take-make-dispose" model implies a greater emphasis on new products, servicing, resource pooling and marketing concepts.	- CE considerations may prove to be an opportunity for positive business differentiation, the development of new CE-friendly business models, and increasing resource efficiency.
	- The promotion of new business models and consumer awareness of the benefits of a CE is lacking - CE implementation is also dependent on its ability to overcome short term barriers constraining its further development, especially financial issues	- Government's role is central in ensuring adequate regulatory frameworks, and encouraging the awareness of actors and social participation, but also in addressing financial lock-ins, and encouraging the financial sector to capture investment opportunities for the CE.
	- EI as a tool to address bottlenecks in product durability and quality, in designing efficient products and "dynamic CE business models". - Ambiguous value of circular business models and EI's environmental credentials (greenwashing)	- Innovation studies have often been near-sighted regarding new forms of innovation, favouring an analysis of the incumbent and most visible actors (e.g. manufacturing, high-tech, big firms, etc.) while somewhat overlooking citizens, consumers and civil society influences

Table 52 - Research overall findings and implications by level

9.3.Main policy implications

The above set of observations and implications can support a debate regarding possible public policy priorities and measures with the potential to positively act upon the transition to a CE. Overall, throughout this research, several policy implications were found, that can now be discussed (summarised in Table 53).

One set of implications concerns the appropriation of the CE concept by the policy agenda worldwide (from Western and Asian countries alike) in the last years. This momentum can be used by nations to drive more comprehensive pro-sustainability policy definitions profiting from CE characterisation as a more tangible, and operational concept and from EI as transition vehicle. Taking advantage of this context could be useful to rethink innovation policy and its economic, environmental and social impacts in light of transformational innovation and CE. That is, redirecting innovation policy instruments to address market and system failures leading to underinvestment and promoting "circular" behaviours and mind-sets.

Secondly, the adoption and acceleration of a CE can be facilitated by the establishment of explicit and coherent political strategies. This relates with decision-makers and public bodies' coordination role. As CE was found to be driven particularly by "softer" (i.e. social, regulatory or institutional) factors, those actors have a crucial role in planning, providing institutional standards and guidance, as well as in R&D support and increasing social awareness. An agenda setting should therefore strive to:

- integrate the already existent multiplicity of initiatives and regulatory frameworks in a more coherent strategic roadmap, in order to avoid mismatches and contradictory incentives. For instance, in the EU current fiscal policies continue to be considered supporting a take-make-dispose economy (Sans et al., 2017), maintaining subsidies contributing to pollution and conciliating conflicting inducements (e.g. promotion of product efficiency and, at the same time, stimuli for the replacement of old appliances);
- address financial lock-ins (regarding large capital requirements, significant transaction costs, high initial costs, asymmetric information, uncertain return and profit), and encourage the financial sector to capture investment opportunities for the CE;
- invest in innovative pilots and R&D support, not only in technological intensive sectors but also in circular business models innovation in areas as "product

service systems", "performance-based contracting", "product as a service", sharing/leasing, and "servitization" (i.e. provision of a service rather than ownership);

- stimulate market activity (e.g. public procurement), as well as establishing an enabling environment for EI;

- address consumer/user awareness and engagement in CE (change "minds and habits") e.g. endorsing information provision (facilitating consumer communities; using digital and social media and the web at large in order to promote co-creation, improve existent labelling and certification systems as to provide clear information regarding effective "circularity" of the good/service, increase credibility as to oppose "greenwashing" rhetoric); providing a solid education system thus promoting more social participation in these issues;

- improve stakeholder involvement in strategic definition as to gather information concerning main barriers and opportunities in each sector, but also be able to align sectoral interests in a common direction, at the same time sharing success stories;

- strengthen and streamline the cooperation between actors, especially interfirm relationships along the value chain, and between the public and private sectors (at a cross-sectoral and cross-regional level) - emphasising transformative EI as a tool for identifying symbiotic links between organisations and sectors (facilitator of sectoral or regional systemic integration), for addressing technical issues such as solid waste, air pollution, water contamination and noise pollution (i.e. bottlenecks for transition providing new ways of sharing services, utilities and by-products among diverse industrial processes or actors), but also to engage in financial engineering (i.e. responding to high initial costs and capital investments).

Nevertheless, even if major trends can be observed, the adequate "policy mix" towards a CE proves to be contextual. As a result, considerations must be carefully made in a country-by-country/sector-by-sector basis in order to make the most of the variety of opportunities and challenges in transitioning towards a CE. As a result, policymakers should map and engage relevant stakeholders for assessing sectoral CE opportunities within the economy possibilities. The following section addresses the CE dynamics in the specific Portuguese case.

Chapter	Main Focus	Main policy implications
2	**Conceptual Definition EI-CE**	- EI transition towards a CE is both uneven (as some activities or sectors will change sooner than others) and destabilising (as pro-CE factors and actors will encourage others to change too). - Urgency to understand how, and by which means, innovation is able to facilitate the emergence of a CE.
3	**EI-CE connections by level**	- Public agencies have a crucial role in planning, providing institutional standards and guidance (infrastructures provision/ conducive legal system). - Pro-CE innovation policy is to provide R&D support, but also should facilitate peer-to-peer information exchange
4	**Enabling and constraining factors in the EI-led transition to a CE**	- Institutional framing is in itself a driver, but it also carries risks for a CE. A coherent strategic roadmap is therefore essential for avoiding mismatches and contradictory incentives. The focus on the promotion of systemic EI is also of paramount importance. The challenge is, nonetheless, to direct “innovation systems” towards CE-inducing productive and social practices.
5	**Indicators of transformational socio-techno-economic change**	- Indicators present analytical priorities framing mind-sets and shaping policy goals. Considering CE, even if some efforts to developed and adequate indicators to its specificities are underway, monitoring and assessing still proves a challenge, even more when trying to assess “CE-friendly” innovation. - An “EI circularity assessment compass” could be used to appreciate both the dynamics and the inertia of the CE.
6	**Patents as indicator**	- The evidence from the proposed “EI circularity assessment compass” approach of the defined pro-CE technological EI patent analyse may be valuable for statisticians, innovation intelligence experts and policy-makers to inform policy making in science, technology and innovation areas.
7	**Trademarks as an indicator**	- Tracking incremental, service-oriented, SME-intensive progress towards a CE using trademarks may be of value to managers, researchers and policy-makers concerned with CE’s implementation considering a “softer” side of EI.
8	**Main socio-cultural, organisational, and policy implications of the CE-EI relation**	- Public policy measures (e.g. legal frameworks, taxes, incentives, infrastructure development) addressing market failures, technological limitations and socio/cultural difficulties. - Importance of diffusing CE related information for both enterprises and civil society (campaigns to promote CE and support market awareness, as well as the penetration of innovative projects - e.g. public procurement). - Gap of policy intervention as priorities are more focused on technological barriers underestimating other economic and socio-cultural non-technological factors - Financial instruments that take into consideration non-technological innovation, like business model innovation, seem somewhat overlooked even if consensually found important - Relevance of promoting cooperation between actors, changing customer preferences to, and business action towards, CE models. - Emphasis in inter-firm relationships in the innovation process, especially the development of networks between firms along the value chain. - Strengthen consumer awareness, still stifled by price considerations, ensure the availability of clear information regarding effective “circularity” of the good/service, and guarantee credibility against “greenwashing” rhetoric. - Seek integration of already existent initiatives in a coherent strategic roadmap, in order to avoid mismatches and contradictory incentives. - Align policies at several levels and areas, linking bottom-up measures to already existent top-down policies.

Table 53 - Overall main policy implications per chapter

9.4.Portugal innovation dynamics - CE opportunities and challenges

The use of the Portuguese example throughout the research accomplished two key purposes. First, as this work wanted to examine potential indicators to assess innovation systems' "circular characteristics", Portugal presented a "test subject" for proxy testing and validation. Secondly, the analysis enabled in-depth insights on the inner workings of the Portuguese innovation system, and its own "circularity". As a result, this second aspect constitutes a research output with its own merits, worthy of critical discussion to draw conclusions regarding the challenges and opportunities posed to Portugal in the implementation of a CE. This avenue of analysis may also prove interesting in comparative works regarding other advanced and/or catching-up countries.

As mentioned in previous chapters, the Portuguese case was chosen due to its specificities. In a globalised and ultra-competitive world, bracing in on one side economic crises and significant economic and structural problems, and in the other constant efforts to "catch up" to the EU political agenda, Portugal has been showing a serious compromise to encourage the transition to a CE (Government of Portugal-Ministry of Environment, 2014, 2017a, 2016).

Regarding innovation dynamics, after initiating a truly scientific revolution that boosted maritime exploration and started the first wave of globalisation in the fifteenth and sixteenth centuries, Portugal lagged behind the innovation processes until the mid-twentieth century (Caraça, 2013; Gonçalves, 2011). Only after the 1950's innovation policy gained relevance with efforts to map and measure knowledge-intensive activities, following OECD's guidelines (Godinho, 2007). The deployment of such innovation policies, i.e. "market intervention", was justified by knowledge's 'public good' characteristics, and the need to intensify investments in science to a 'optimal' level by, for instance, funding universities and research institutes, or reinforcing legislation in intellectual property rights (Nelson and Winter, 1982; OECD, 2010b). Therefore, a first phase, focused on investments on S&T infrastructures (1960's), was followed by incentives to specific sectors of activity (1970's), especially on industrial policy and in fostering links between universities and business (1980's), and on increasing the quality of R&D (1990's) (Ferreira, 2005). Since the 2000's the innovative performance of the Portuguese economy improved and innovation public policies were consolidated, moving from a linear perspective of innovation (focused only in base science) to a more integrated view (Godinho, 2013). Several programmatic strategies[127] were launched to support S&T and the innovation society, namely the Integrated Innovation Support Program (PROINOV - between 2001 and 2003) where main agents of the Portuguese innovation system were identified; and the Technological Plan (2005-2011), for coordinating innovation policies (Santos, 2016). Currently, the *Portugal2020* program stands out, a financial instrument spanning from 2014-2020, drawing on the principles of the Europe 2020 strategy for smart, sustainable and inclusive growth.

In the intersection between EI and CE two programs can be highlighted: the Competitiveness and Internationalisation Plan (POCI / COMPETE 2020), focused on R&D, innovation and competitiveness; and the Operational Plan for Sustainability and Resource Efficiency (POSEUR), aiming to promote a more efficient use of resources and reducing pollutant emissions (COMPETE 2020, 2014; Portugal 2020, 2014; Poseur, 2014).

At the same time, Portugal made a significant effort to transpose EU directives on the environment, significantly improving the political and regulatory context to support both innovation and environmental protection. As pointed in Chapter 4 (4.4.) and especially following the EU 2015 Action Plan (EC, 2017b, 2017a), Portugal pursued several initiatives focused on overcoming the "web of constraints" (see Dijk and Kemp, 2016) of intertwined factors - hard and soft, that hampers the further implementation of a CE. At technical level several initiatives were launched since 2015 targeting EI in industry and attempting to be "living labs" to pilot technologies like: the Efinerg[128]; the Ecoprodutin[129]; and the Interambinerg[130] projects (EC, 2017b). Regarding financing programs, the H2020 call focused on "Industry 2020 in the Circular Economy"[131], already counts 23 approved and financed projects with Portuguese participation (4 coordination's and another 19 projects with Portuguese

[127] For a compilation on main publications on innovation policy in Portugal and main programmatic strategies to support innovation between 2001-2013 please see Santos, 2016.
[128] Focused on the promotion of energy efficiency in industry, this project main objectives are to raise awareness and to inform industry of the advantages of sustainable economic practices by helping to identify specific solutions tailored to each sector (Efinerg, 2015).
[129] Aimed at EI as a strategic factor for the productivity and competitiveness of Portuguese companies, this project has as main focus the development of more efficient ways to use natural resources and production processes (Ecoprodutin, 2015).
[130] Focused on the internationalisation of the Portuguese environment and energy sector (Interambinerg, 2015).
[131] Intends to support the goals of the Circular Economy Package by demonstrating the economic and environmental viability of CE and by deploying new approaches and technologies.

institutions partnerships)[132]. At a more institutional level, the *Green Growth Commitment* was adopted by the Portuguese government in 2015, linking several types of stakeholders on reorienting the country's economy. New types of policies were also introduced in 2015, like the Green Taxation Reform, following the rationale that taxing pollution and resource use, enables important social and environmental benefits towards more sustainable economic development models (EC, 2017b).

Nevertheless, even if in the last years Portugal achieved a status of "moderately eco-innovator" (EIO, 2014) and ranked in the 17th place on resource productivity (EU-28) (EC, 2017b), there is still great potential to be developed in these areas. As the EU Environmental Implementation Review stressed "Portugal still faces considerable challenges in the area of water and waste management, air quality and nature conservation. Furthermore, in overall, environmental implementation and enforcement represents a challenge for Portugal" (EC, 2017b, p. 4). Several weaknesses, discussed in detail throughout this research[133], still constrain the Portuguese innovation transition towards more "circular" paradigms. The empirical analysis both in patents and trademarks reinforced the perception of a significant vulnerability on (internal and international) macroeconomic dynamics. The upward trend on patents and trademarks applications around 2000 was interrupted after 2010, most likely a result of the severe debt crisis and the ensuing austerity policies. A risk adverse society, and unaware consumers, further difficult the development of initiatives.

Concerning technological dispersion, the Portuguese strategy seems, until now, firmly focused on renewable energies generation (e.g. Y02E is the technology class that captures more interest in the patent applications). CE strategies related with "life cycle extension and reconceptualization" that is, technologies focused on resource optimisation like reconditioning and remanufacturing options have been underemphasised. Services, fundamental in a CE, are still surpassed by goods as overall main classes in the trademarks analysis, even if 2015 and 2017 may point to an inversion in that trend. The number of actors in the system is increasing but slowly, with interconnection problems - reduced number of cooperation between actors and a low level of trust. Even if firms and universities have become more active over time (as

[132] https://data.europa.eu/euodp/en/data/dataset/cordisref-data - Last search in February 2017.
[133] Chapter 4.4 - technical, economic, institutional, and social driver for overcoming CE barrier; Chapter 6 – patents; Chapter 7 – trademarks.

stressed in the patents' observations) the predominance of singular inventors and of start-ups reflects a fragmentation in the entrepreneurship structures in Portugal.

The overall strengths, weaknesses, opportunities and threats identified in this research were synthesised and systematised in Table 54. Even if these data show a slow and uneven progress, several other signs seem encouraging. In the last quarter of 2017 Portugal launched two important initiatives. The first, the roadmap for carbon neutrality, reinforced the country's commitment to the implementation of the Paris Agreement and to a strategy focused on innovation and low carbon investments. In that context the Ministry of Environment underlined the CE not only as a political goal, but also as a need in the decarbonisation of society (Government of Portugal- Ministry of Environment, 2017c, 2017d). The second, the Portuguese Action Plan for the Circular Economy (PAEC) focusing on 7 main actions[134], places a particular emphasis on mobility/transportation sector and in urban rehabilitation (Government of Portugal- Ministry of Environment, 2017a, 2017e). In that regard, the Ministry of Environment stressed the importance of an economic redirection to new models, distanced from the consumption of resources, and the potential benefits of a CE. Mentioning the European Union studies the expectation of job creation of around 57 thousand jobs by 2030 in Portugal was also underlined (Government of Portugal- Ministry of Environment, 2017e). Both these programs may be determinant to respond to some of the weaknesses hampering the system. However, this seems dependent on a broad effort to align policies at several levels and areas, using both supply, demand-side and contextual instruments in a clear strategy for pro-CE EI.

[134] Specifically: 1) Reduce demand for materials and raw materials. Increase reuse of products covered by extended producer responsibility; 2) Analyse the economic and environmental potential of the progressive introduction of economic instruments to reward sustainable production and consumption. Encourage the financial sector to capture investment opportunities for the CE; 3) Educate citizens for environmentally conscious choices ; 4) Strategy for Combating Food Waste; 5) Decrease waste production and Increase the introduction of secondary raw materials in the economy; 6) Increase water efficiency, water reuse, and reducing water consumption; 7) Definition of areas of research and innovation key to the acceleration of the CE in Portugal (Interministerial Group for the Circular Economy, 2017).

	Hard				Soft			
	Strengths	**Weaknesses**	**Opportunities**	**Threats**	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**
Macro	-Numerous energy and waste management policies and investments carried out in Portugal since 2000 -Portugal has been promoting several other legislative initiatives, like the 2015 Green Taxation Reform	-Prevalence of energy and waste policies -Lack of systemic integration of measures	-Integration into an European market strategically focused on CE and EI, with great potential for growth -Potential implications for the definition of public policies in Portugal would underline the need for investing further in pro-CE policy evaluation exercises and stress the urgency of further synchronising environmental policy and science, technology, innovation and entrepreneurship agendas -Portugal could improve areas where a sound knowledge base and good practices already exist: e.g. there is space to continue the implementation of a broader "Green Tax Reform" -Take advantage of the recent increase in technological development in the construction and transportation sectors (stressed in the patent analysis) to boost other sectors -Use Public procurement measures to boost commitment and awareness to circular practices	-Economy remains predominantly specialised in low technology intensity sectors -Country's vulnerability to (internal and international) macroeconomic dynamics hampers technological investments -Lack of a clear strategy for pro-CE EI, rooted in coordinated policies and regulations may severely hamper progress	-Portugal has been developing several strategies to reorient the country's economic development towards a CE where a social component and a focus on "green behaviour" is increasingly stressed, namely the *Green Growth Commitment*; the roadmap for carbon neutrality and the Portuguese Action Plan for the Circular Economy (PAEC)	-Oscillations in trademark applications may point to a demand-side also very vulnerable to (internal and international) macroeconomic dynamics	-The seemingly (slow) growth of services that appears to have been initiated since 2015 should be incremented -The implementation of a CE could benefit from a more demand side/ social perspective focused on sustainable consumption/ lifestyles and enhance credibility (combat "greenwashing") -Financial instruments should take in consideration non-technological innovation	-A coherent strategy must be followed to avoid misaligned incentives that may hamper further development of the CE

Meso	-Slight increase in collaboration between companies and universities	-There is already a significant number of actors, however, there is still little cooperation between companies and between companies and other actors	-Stimulating interfirm relationships and cross-department collaboration in the innovation process, especially the development of networks between firms along the value chain	-High risk and the difficulty of competing in international markets (due to the high implementation costs), adding to difficulties regarding financing	-There are already some agents (companies; start-ups; and associations) actively engaged in pro-CE innovation not only in technological areas but also in service innovation	-Links and relations between agents are not evident. Lack of collaboration between agents can limit further development	-Increase collaboration and networks between agents -Integrate other actors besides enterprises and universities (reinforce the social dimension)	-Speed of progress and development is slow and uneven
Micro	-Growing number of companies investing in CE EI	-Barriers to innovation (e.g. high costs and financing) -Companies fail to recognise academic contributions as important sources of information for innovation.	-Potential for national and international cooperation	-Dependence on public investment and initiative	-Increase of start-ups linked with CE in the trademark applications	-There are still only a small number of actors involved in these dynamics	-As start-ups have been linked with the emergence of sustainable business model innovation, the important role of start-ups in trademark applications suggest a potential increase in CE business models awareness in Portugal since 2013, which could be further promoted	-Entrepreneurship structure still mostly limited to small enterprises and start-ups somewhat constraining a broader implementation of a CE

Table 54 - Synthesis of overall strengths, weaknesses, opportunities and threats identified in the research for Portugal

9.5. The "great divergence" or the "bound" Prometheus? Globalisation challenges and a Circular Economy

The period between the end of the eighteenth century and contemporaneity encompassed change at a pace never seen before. The "Great Transformation" of the "long XIX century" marked the affirmation of a market economy dominating all dimensions of society (Hobsbawm, 1975, 1978, 1987; Polanyi, 2001), where capitalism and economic development deeply shaped social interactions and the evolution of political organisations (Moore, 1993). Globalisation was underway, promoted by easy access to natural resources (Pomeranz, 2001) and technological developments (Goldstone, 2008).

After the intense transformations of the World Wars and their inescapable impact on the world, nowadays globalisation is much broader, encompassing complex problems like inequality, human rights and sustainability (Hicks, 2017). Considering in particular the boundary-less nature of sustainability, the question on how to curb and accommodate climate change and limit environmental degradation and depletion is bound to be a global defining societal puzzle (Vazquez-Brust et al., 2014).

Building on the Schumpeterian framework of innovation as a process of "creative destruction" and introduction of "new combination" of ideas and factors of production for economic development (Schumpeter, 1928), economic trajectories can be seen as intrinsically innovation-intensive processes of reconfiguration and adaptation (Fagerberg et al., 2004). However, Landes' (1969) unbound Prometheus[135] has revealed itself to be neither an even process, neither "better" from a welfare or sustainability point of view (Soete, 2013).

As innovation processes enabled the development of a predatory industrial economy, they can also be the vehicle for triggering a new "deep transition" towards sustainability (Schot and Kanger, 2016). This was one of the main points stressed throughout the present research. EI, understood as more than just "green" technology, but rather as a strategic enabler of entire value-chain transformations towards the *recirculation* of resources (through refurbishment and re-manufacturing), *recycling*

[135] Landes used the Prometheus Greek myth of the theft and control of fire as an analogy to XVIII technological advances that drove the industrial revolution and boost a larger process of modernisation and socioeconomic transition (Landes, 1969).

(reconstructing inputs and reshaping outputs) and *renewal* (using clean energy and eliminating waste), i.e. towards a CE.

Research regarding those issues is in fact global. For instance, searching for “circular economy” in the title, abstract or the keywords of the WoS database, and inputting the coordinates of authors’ affiliation countries[136], enables a visualisation of the diverse geographical locations where CE investigation is now being produced (Figure 39).

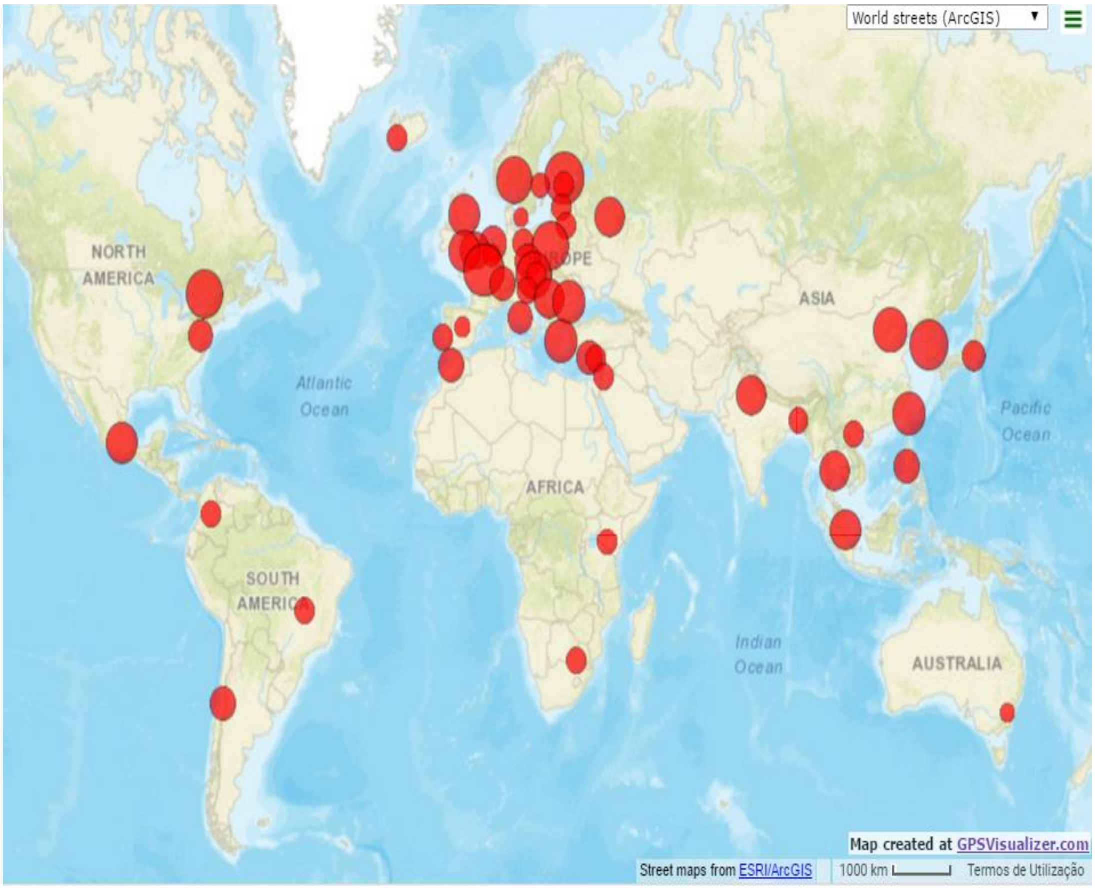

Figure 39 - Geographical distribution of affiliation nationality of authors of CE papers
Note: The geographic coordinates were uploaded into gpsvisualizer.com for generating the map. Each circle represents a country, focusing on the capital city, and its relative size the number of publications with the “circular economy” descriptor originated there (country of author affiliation).

[136] Last search in November 2017 including all documents (articles, proceedings papers and reviews) published in journals, books or symposium/conference series.

While several trends are cross-cutting[137], CE and pro-CE EI understanding, awareness, and implementation appear to have different rhythms and specific barriers across the world. Country specificities seem to matter. Geographic location, income level, growth rate, policy frameworks and economic governance, demand conditions, these are all factors that influence innovation pathways (Altenburg et al., 2016; Schmitz and Altenburg, 2016). A very heterogeneous picture stands out when considering the 2005 overwhelming low global recycling rate of 6% (Haas et al., 2015), even if several countries seem slowly becoming aware of CE potential in job creation (Mitchell and Morgan, 2015), resource productivity (EC, 2014g), market value (Bastein et al., 2013), trade balance, and CO2 emissions reduction (Wijkman and Skånberg, 2015).

In Europe, environmental regulations, have been addressing energy efficiency and waste management since before the 1990's, however with very heterogeneous paths when establishing a comparison between EU countries. Northern countries, namely Denmark, Germany, Netherlands, and the UK are front runners in waste recovery and recycling (Reike et al., 2018). These are also the leading countries in the development of integrated CE strategies and Action Plans (EMF, 2016a; Government of Netherlands, 2016; State of Green, 2016). This progress, nevertheless, coexist with different realities like, for instance, in eastern European countries, where weaker environment protection regulations and almost inexistent recycling rates can be found (Domenech and Bahn-Walkowiak, 2018; Reike et al., 2018). More recently, the 2015 *EU Action Plan for the Circular Economy* promoted a policy push committing €222.7 million to support Europe's transition to a more "closed-loop" future (EC, 2015a, 2017a). It was taken as a device to frame several measures and further boost (and fund) CE initiatives throughout Europe, in order to support catching-up countries lagging behind and at the same time inspire frontrunners to further CE (Domenech and Bahn-Walkowiak, 2018; EC, 2015a, 2017a).

In the United States, there are several differences in the perception and application of CE, with "industrial ecology" prominence as a circular strategy. Overall, actions there have been more circumscribed and focused on local level initiatives. For instance, the City of New York restricted the sale of single plastic-foam (New York

[137] Innovation capabilities are not built in isolation, mutual influences do occur. For instance comparing Asian and European countries, in low-carbon innovation in wind technology, Altenburg et al.(2016) stress the strong interactions and interdependences between countries with several joint ventures and R&D cooperation (Altenburg et al., 2016; Schmitz and Altenburg, 2016).

City Council, 2013) and Chicago defined a recycling target of 50% for all construction and demolition waste (City of Chicago, 2014). However, recycling rates were in 2013 only around 34%, with 53% of municipal solid waste still being landfilled (Reike et al., 2018). Current political context in regard to sustainability may bring additional challenges in the near future.

In Asia, Japan launched in 2000 the “Basic Law for Establishing the Recycling-based Society” and developed several “Eco-Town programs” initiatives of urban symbiosis (van Berkel et al., 2009). In 2010, Japanese recycling target rates in several materials (glass, paper, construction waste, and even in food waste) were all above 40% (e.g. the rate of glass recycle was of 91% and of construction waste: 95–98%), revealing this country’s ambition in the field (Reike et al., 2018). China has proposed explicit CE legislation formally introducing the *Cleaner Production Promotion Law of* 2002. Since then CE entered Chinese national policy and regulatory priorities, with several legislative efforts focusing in cleaner production and eco-industrial parks development (Geng et al., 2014, 2012).

Limited information can be found concerning countries from the global South, either emerging fast growing countries like Brazil, India and South Africa, or other lower-income developing countries. Considering the resources and waste growing trends, these countries undoubtedly face major problems concerning environmental outcomes (Preston and Lehne, 2017).

A CE could present several opportunities to these economies. In their efforts to catch up, an early implementation of CE strategies could prove interesting due to the flexibility of the systems, as to avoid linear lock-ins that are so usual in mature economies (as the reconfiguration of large parts of the system is very difficult). Taking advantage of markets globalisation and technology transfer (namely by the displacement of several R&D operations of globalised companies to these countries, but also by foreign direct investments, imports, licensing, etc.) can also assist these countries in leapfrogging towards more sustainable technological pathways (Schmitz and Altenburg, 2016).

Some recent reports have been starting to point out the potential benefits of CE to large, fast developing countries (Altenburg et al., 2016; EMF, 2017, 2016b;

Mativenga et al., 2017b, 2017a), but also in lower-income countries like Morocco[138], Algeria[139], Cameroon[140], or Laos[141] (Authier, 2016; Deloitte and Declic, 2016; Diaz, 2017; GIZ, 2014). For instance, the African Development Bank is already exploring CE as an approach to support its industrial development strategy (Preston and Lehne, 2017). Several opportunities have been emphasised considering the economic benefits of inserting CE activities in the formal economic circuits and in the management of secondary raw materials. In 2016, the EMF estimated that the implementation of a CE in India could, compared to the current development scenarios, create an annual value of around US$ 218 billion in 2030. In the mobility sector it could reduce around 38% of vehicle kilometres travelled on roads by 2050, with significant impacts in transit congestion, pollution, but also public health improvement (EMF, 2016b). Other opportunities in lower-income contexts may arise from harnessing "frugal innovation", i.e. innovation focusing in doing more with less, for CE development (Levänen and Lindeman, 2016; Radjou and Prabhu, 2015).

As a matter of fact CE is already practiced in several of these countries, even if in most cases in an informal way (Diaz, 2017). In India, for instance, repair and reuse habits are very ingrained, but local waste management infrastructures underdeveloped (EMF, 2016b). That is to say that CE's implementation in these countries, as well as the role played by EI, will contrast with the reality observed in European countries. This is an avenue for important further research. First, where in the value chains are CE activities initiatives being driven in these countries? Focus seems to be most commonly placed in the end of cycle, resulting in sub-optimal economic and environmental impacts. Secondly, are those activities really transformative or merely the continuation of a previous *status quo*? For instance, there is a risk that as *per capita* income increases, and the middle class grow in size, some of reuse and repair activities become less attractive and a use-and-discard attitude assumed. Lastly, how existent CE activities already in place can be improved and enhanced? Or even better, how can they be

[138] Morocco have been developing a National Strategy for Sustainable Development in which CE is emphasised and recently, in 2016, the production, import, export, marketing and use of plastic bags for packaging was prohibited (Authier, 2016; Deloitte and Declic, 2016).
[139] The "Gestion des déchets et économie circulaire" project is a programme implemented between 2014-2019 in the Algerian cities of Annaba, Setif and Tlemcen that aims to improve institutional/administrative/private capacities in the waste management sector (GIZ, 2014).
[140] There are already some research regarding CE in Cameroon, especially in the development of theoretical models about Corporate Social Responsibility in the context of an African country (Ntsonde and Aggeri, 2017).
[141] The government of Laos is exploring how could CE strategies be used to boost local industries (Ministry of Energy and Mines Lao PDR and UNDP, 2017).

included in a comprehensive strategy for transition to a CE (Deloitte and Declic, 2016; EMF, 2017, 2016b; Mativenga et al., 2017a; Ntsonde and Aggeri, 2017)? As is the case with high income countries, a systematic approach and strategic definition is needed to frame CE development in these countries. Nonetheless, they face even more challenging innovation barriers, needing a deeper rethinking of innovation systems and policy mixes. Pathways are political and context-specific and some may be lagging behind in the developing of support conditions (Schmitz and Altenburg, 2016). The needed institutional framing is normally high, while government capabilities to foster it may be weak (Cirera and Maloney, 2017). Lack of specific policies, rules and regulations, as well as a limited supply in human capital, hamper further developments (Diaz, 2017). Other issues concern the ability to enforce existent regulations, due to reduced capabilities to effectively monitor lack of conformity and high levels of corruption (Hoque et al., 2014). Countries economically fragile, politically unstable and/or with terrorism problems tend to be less preoccupied with environmental issues (Ntsonde and Aggeri, 2017). All these factors directly impact technological development. Even when technological transfer occurs, it is not clear how much these countries are really able to take advantage of that situation or how does it stimulate new innovation pathways (Schmitz and Altenburg, 2016).

All this implies that policy adaptation is difficult. Instead, focused actions in selective issues are recommended. Therefore, policies and actions to foster pro-CE EI have to be reflexive and dynamic, focused on adaptation to change. In this regard a significant gap of knowledge still exists. Table 55 tried to present the primary differences between countries, nonetheless being far from exhaustive. More academic research is needed to understand CE trajectories and specificities on these rapidly growing, increasingly urbanised, countries.

Upper Income Countries	Lower Income Countries
-Main focus in energy efficiency (renewables) and waste management (recycling)	-Main focus is waste management
-Downcycling is still the rule but there are already upcycling examples	-Downcycling is still the rule
-Formal markets	-Informal markets (especially in recovery, recycling and reuse sectors). -Countries have already several CE practices in place, however it is necessary to turn them into development opportunities (higher-value, employment-generating opportunities yet to be captured)
-Policy's framing conditions have been developed but still not considered enough -Further diffusion of CE related information for both enterprises and the civil society needed	-Lack of policies and formal structures. Absence of expertise and specific education at all levels (Human Capital). Limited regulations (rules and regulations) and enforcement capacities
-Infrastructures already in place	-Inexistence of essential infrastructures
-System actors exist but in some cases showing limited links between them	-Lack of system actors and coordinated networks
-System lock-ins (difficulty to overcome difficulties in reconfiguration of resource-intensive practices and infrastructures) especially in energy and transportation systems.	-Benefits from implementing a CE from scratch - Flexibility of the systems (avoid linear lock-ins) - When possible there are advantages regarding "tapping" into several tested technological advances, rather than having to go through the entire technological trajectory (use of foreign direct investment, imports, licensing, etc.)
-Financial instruments already exist (E.g. in the EU the H2020 financial pack may function as a complement to national policies) but is mainly focused on technological innovation (non-technological innovations are somewhat overlooked, even if consensually found important)	-Insufficient funds dedicated to CE (lack of development of financial instruments) -Potential contribution of 'frugal' innovation i.e. low production costs, high-quality products and services

Table 55 - Main differences in CE from developing and developed countries

9.6. The future is upon us – Contributions, limitations, and emergent issues to further research

How to face the socio-economic effects of environmental issues (pollution, climate change) deriving from the "take-make-dispose" model? The CE approach was taken as a starting point to explore and illustrate EI's role in fostering a targeted socio-techno-economic change. To explore that relation, this research focused in three main research questions aiming to add to the conceptual definition and theoretical links between the two concepts; debating the use of "new" empirical tools to best monitor pro-CE EI; and practical aspects concerning implications of the CE-EI relation to socio-cultural agents, organisational strategies and policy priorities.

In this process a mix method approach was followed, using a wide range of methodologies, from literature review, to the use of bibliometric tools, patent and trademark analysis and a foresight Delphi exercise. This final section aims to make overall considerations regarding the research's approach; point out main theoretical, empirical and practical contributions; underline limitations; and reflect upon emergent issues and further research in this area (compiled on Table 56).

The research adds to the ongoing discussion on sustainability by exploring EI and CE definitional questions at the point where these agendas intersect. The interpretation-rich and hands-on approach to bibliometric data, based on two types of literature sources (academic -WoS and Scopus papers; and grey -reports and policy papers), enabled an in-depth conceptual and theoretical analysis of both CE and EI. This revision provided a way for thinking about key themes and main links between the two concepts, in order to outline broad influential types of EI within specific levels of a CE, and a better understanding on how processes of innovation shape the transition, at the same time, enabling preliminary considerations regarding policy and business implications. This links with the need to establish a shared terminology when talking about CE as to prevent oversimplifications, misappropriations and ambivalences that may hinder the usefulness of the approach. Concerning innovation, the review also allowed reflections on the "transformation turn" in innovation studies and their reconfiguration towards a more "pro-environment" agenda. In the assessment of the connection between EI and CE, it became evident that the credit given to the CE approach as a socio-technical template for replacing an old linear unsustainable economy with a more regenerative system is dependent on the introduction of transformative environmental innovation (which we called EI) in that "deep transition". A CE is contingent on systemic EI combining "harder" environmentally-sensitive innovation, but also "softer" changes in societal systems and business models; the challenge remaining on how to grasp, direct and monitor "innovation systems" towards those "circular" practices.

The unavoidable methodological constraints of "meta" studies, related with randomisation and the representativeness of the sample (Li and Zhao, 2015), is the main limitation in this part of the research, pointing to areas for future research. The connections between the CE and EI could be further addressed regarding specific sectoral EI tools required for achieving a ("transformative" and "systemic") CE "transition". Also, the way in which CE and EI concepts are used and understood varies from stakeholder to stakeholder. A better understanding of these diverse perspectives is needed in order to better tailor strategies and policies.

As for empirical contributions, the current limitations in diagnosing innovation systems' circularity capacities validated the exploration of novel tactics to identify potential indicators. The use of "harder" (patents - techno-economical), and "softer" (trademarks - social and cultural) proxies enabled a broader view concerning technological and non-technological innovation trajectories towards a CE. Combining *scalability* (can be used to cover firms, sectors, regions or countries); *multidimensionality* (including several areas); and *modularity* (enabling the use with other indicators), these proxies seem reliable and revealing. The use of the Portuguese case for the proof of concept further stressed potential application of these proxies, even if some worth mentioning limitations exist.

In the patent analysis, the limitations concerning the EPO's Y02 class and the patents codification process (derived from the CE literature) add to the inherent restrictions of the indicator. To lessen these issues several actions were taken to increase the validity of the exercise and validate both the criteria and codification process (Bengtsson, 2016). Naturally, further research could broaden the sample and carry out comparative studies in order to refine the results and improve the methodological underpinnings of the methodology. The evidence and methodological approach seems a valid starting point while future research could come to explore the possibility to measure patents' "degree of circularity" or use econometric or text mining methods for further analyses.

Regarding "soft" indicators, other metrics like design and environmental certifications, are still to be substantially used in CE assessment. This seems an interesting angle for further research, since the trademark-based proxy used in this work proved rather informative. For instance, concerning design, the recent Eco-Design Directive, promoted within the legislative proposal of the Circular Economy Action Plan has been stated as contributing to positive environmental performance and competitiveness of enterprises. Nevertheless, the instrument has been criticised regarding its incomplete coverage and slow development (Domenech and Bahn-Walkowiak, 2018). This may be a path for further exploration.

Finally, in order to "make sense" of previous findings, a foresight exercise enabled gathering iterative and interactive insights of CE specialists in order to harness non-explicit knowledge. CE and EI were explored as real-world phenomena in the consideration of their relevance both as a public policy tools and strategic objectives. The use of the Delphi method, allowed for the recognition of several policy priorities and organisational strategies with the potential to positively act upon the transition to a CE. A systemic action appears grounded on coordinated policies and regulations, not isolated initiatives, at several levels and areas, using both supply, demand-side and contextual instruments and financial and non-financial incentives. Regarding financial support, an analysis concerning existent instruments' proficiency in financing CE projects is still lacking. Mechanisms like green bonds (EC, 2016c) or the funding opportunities of H2020 "Industry 2020 in the Circular Economy" call (EC, 2015d) are still understudied. As for society, the role of consumers as "part of the supply chain" and "innovative agents" in the development of a CE still has not been properly addressed. CE's "geography" is also an issue needing further development, as there is still a heterogeneous spatial dispersion concerning understanding and implementation of CE. Meaning and examples greatly differ from country to country, and a better understanding of interactions and linkages, as well as trade-offs and mismatches, between technological and socio-institutional systems, could be of importance. Other areas of possible development could be looking into the implications for innovation towards CE in fast developing high growth countries and how they may be expected to differ from previous examples.

	Contributions	Further research
Theoretical/ Conceptual	• EI and CE working definitions. • Clarification of the intersection between EI and CE at several levels. • Development and application of a "focusing device" distinguishing between "harder" (techno-economic) and "softer" (social, institutional) EI factors in the transition to a CE.	• The connections between the CE and EI could be further addressed regarding specific sectoral EI tools required for achieving a ("transformative" and "systemic") CE "transition". • The way in which CE and EI concepts are used and understood varies from stakeholder to stakeholder. A better understanding of these diverse perspectives is needed in order to better tailor strategies and policies. • Country to country heterogeneity in the implementation of the CE; breakdown by region (e.g. EU vs. US vs. Asia vs. others). • Other techniques (such as text mining or content analysis may be able to take this research further.
Empirical	• Definition of an "EI circularity assessment compass". • Operationalisation of hard (patents) and soft (trademarks) proxies to assess pro-CE EI. • Proof of concept applied to the Portuguese case.	• Expand analysis to other case studies and extend to regional analysis. • Hard Indicator - could patent's "degree of circularity" be assessed? • Soft Indicators - Test other indicators, namely design based proxies and other trademarks base indicators like "Collective Trademarks" (Certification) or Industrial Design.
Practical	• Discussion regarding CE approach within the sustainability debate and future developments. • Central role of systemic EI in the transition for a CE. • Identification of innovation policy goals towards a CE.	• Gap of knowledge regarding the impact of EU's CE Action plan strategy and legislative proposals on overcoming CE barriers already identified (sectoral analysis). • Gap of knowledge on the financing of CE projects. For instance, it would be interesting to explore H2020 financial support or green bonds. • Scarcity of comparative studies across countries. • The role of consumers as "part of the supply chain" and "innovative agents" in the development of a CE still has not been properly addressed. • What are the implications for innovation towards CE in fast developing high growth countries?

Table 56 - Summary of main contributions and clues to further research

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LIST OF FIGURES

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APPENDIXES

Appendix 1 - Academic papers in literature review

	Database	Date	Source	Title	Source	Vol
1	WOS	1992	(Ausubel, 1992)	Industrial ecology - reflections on a colloquium	Proceedings of the national academy of sciences of the United States of America	89
2	WOS	1992	(Davelaar and Nijkamp, 1992)	Operational models on industrial-innovation and spatial development - a case-study for the Netherlands	Journal of Scientific and Industrial Research	51
3	WOS/ SCOPUS	1998	(Koenig and Cantlon, 1998)	Quantitative industrial ecology	Ieee transactions on systems man and cybernetics part c-applications and reviews	28
4	WOS/ SCOPUS	1998	(Naveh, 1998)	Ecological and cultural landscape restoration and the cultural evolution towards a post-industrial symbiosis between human society and nature	Restoration ecology	6
5	WOS/ SCOPUS	1998	(Pizzocaro, 1998)	Steps to industrial ecology: reflections on theoretical aspects	International journal of sustainable development and world ecology	5
6	SCOPUS	1998	(Rejeski, 1998)	Learning before Doing: Simulation and Modeling in Industrial Ecology	Journal of Industrial Ecology	2
7	SCOPUS	1999	(Robins and Kumar, 1999)	Producing, providing, trading: Manufacturing industry and sustainable cities	Environment and Urbanization	11
8	WOS/ SCOPUS	2000	(Anastas and Lankey, 2000)	Life cycle assessment and green chemistry	Green chemistry	2
9	SCOPUS	2000	(Huber, 2000)	Towards industrial ecology: Sustainable development as a concept of ecological modernization	Journal of Environmental Policy and Planning	2
10	WOS/ SCOPUS	2000	(Moser, 2000)	Scientific methodology for complex systems: Macroscopic patterns in eco- and anthropo-sphere	Acta biotechnologica	20

11	SCOPUS	2001	(Finster et al., 2001)	Linking industrial ecology with business strategy: Creating value for green product design	Journal of Industrial Ecology	5
12	WOS/ SCOPUS	2001	(Moser, 2001)	Engineering for problem solving in future: Eco-social market economy and eco-social tech	Minerals Engineering	13
13	WOS/ SCOPUS	2002	(Aizawa et al., 2002)	Critical issues in promotion of environmentally benign manufacturing and materials processing	Materials transactions	43
14	WOS/ SCOPUS	2002	(Fiksel, 2002)	Sustainable development through industrial ecology	Advancing sustainability through green chemistry and engineering	823
15	WOS	2003	(Thomas and Graedel, 2003)	Research issues in sustainable consumption: Toward an analytical framework for materials and the environment	Environmental science & technology	37
16	WOS/ SCOPUS	2003	(Thomas et al., 2003)	Industrial ecology: Policy potential and research needs	Environmental engineering science	20
17	WOS/ SCOPUS	2004	(Desrochers, 2004)	Industrial symbiosis: the case for market coordination	Journal of Cleaner Production	12
18	WOS/ SCOPUS	2004	(Jin et al., 2004)	The ecological perspective in chemical engineering	Chemical engineering science	59
19	SCOPUS	2004	(Körhönen et al., 2004)	Management and policy aspects of industrial ecology: An emerging research agenda	Business Strategy and the Environment	13
20	WOS/ SCOPUS	2004	(Sterr and Ott, 2004)	The industrial region as a promising unit for eco-industrial development - reflections, practical experience and establishment of innovative instruments to support industrial ecology	Journal of Cleaner Production	12
21	WOS/ SCOPUS	2004	(Yang and Lay, 2004)	Applying ecosystem concepts to the planning of industrial areas: a case study of Singapore's Jurong Island	Journal of Cleaner Production	12
22	SCOPUS	2005	(Bristow and Wells, 2005)	Innovative discourse for sustainable local development: A critical analysis of eco-industrialism	International Journal of Innovation and Sustainable Development	1
23	WOS	2005	(Langen, 2005)	Trends and opportunities for the long-term development of Rotterdam's port complex	Coastal management	33
24	WOS/ SCOPUS	2005	(Mirata and Emtairah, 2005)	Industrial symbiosis networks and the contribution to environmental innovation - The case of the Landskrona industrial symbiosis programme	Journal of Cleaner Production	13

25	WOS/ SCOPUS	2006	(Basu and van Zyl, 2006)	Industrial ecology framework for achieving cleaner production in the mining and minerals industry	Journal of Cleaner Production	14
26	WOS/ SCOPUS	2006	(Cohen, 2006)	Ecological modernization and its discontents: The American environmental movement's resistance to an innovation-driven future	Futures	38
27	WOS	2006	(Crotty and Smith, 2006)	Strategic responses to environmental regulation in the UK automotive sector - The European Union End-of-Life Vehicle Directive and the Porter Hypothesis	Journal of industrial ecology	10
28	WOS/ SCOPUS	2006	(Tombesi, 2006)	Good thinking and poor value: on the socialization of knowledge in construction	Building research and information	34
29	SCOPUS	2006	(Vermeulen , 2006)	The social dimension of industrial ecology: On the implications of the inherent nature of social phenomena	Progress in Industrial Ecology	3
30	SCOPUS	2006	(Walter and Scholz, 2006)	Sustainable innovation networks: An empirical study on interorganisational networks in industrial ecology	Progress in Industrial Ecology	3
31	WOS/ SCOPUS	2007	(Adams and Ghaly, 2007)	Maximizing sustainability of the Costa Rican coffee industry	Journal of Cleaner Production	15
32	SCOPUS	2007	(Cheng, 2007)	China's new development plan: Strategy, agenda, and prospects	Asian Affairs	34
33	WOS/ SCOPUS	2007	(Dewick et al., 2007)	Technological change and the environmental impacts of food production and consumption - The case of the UK yogurt industry	Journal of industrial ecology	11
34	SCOPUS	2007	(Dong et al., 2007)	Problems and strategies of industrial transformation of China's resource-based cities	Resources and Environment	17
35	SCOPUS	2007	(Killerby et al., 2007a)	Chemical modification of timber decking: Assessing the parameters of acceptability	New Zealand Journal of Forestry Science	37
36	SCOPUS	2007	(Killerby et al., 2007b)	Chemical modification of timber decking: Looking to the future	New Zealand Journal of Forestry Science	37
37	WOS	2007	(Matos and Hall, 2007)	Integrating sustainable development in the supply chain: The case of life cycle assessment in oil and gas and agricultural biotechnology	Journal of operations management	25
38	SCOPUS	2007	(Ogunseita n, 2007)	Public health and environmental benefits of adopting lead-free solders	JOM	59
39	WOS/ SCOPUS	2007	(Wen et al., 2007)	Recycle of low chemical potential substance	Resources conservation and recycling	51

40	WOS	2007	(Yarime, 2007)	Promoting green innovation or prolonging the existing technology - Regulation and technological change in the chlor-alkali industry in Japan and Europe	Journal of industrial ecology	11
41	WOS/ SCOPUS	2007	(Zhou and Schoenung, 2007)	An integrated impact assessment and weighting methodology: Evaluation of the environmental consequences of computer display technology substitution	Journal of environmental management	83
42	WOS	2008	(Allen, 2008)	Building Material Flow Accounts in the United States	Journal of industrial ecology	12
43	WOS	2008	(Deutz and Gibbs, 2008)	Industrial Ecology and Regional Development: Eco-Industrial Development as Cluster Policy	Regional studies	42
44	WOS	2008	(Hewes and Lyons, 2008)	The Humanistic Side of Eco-Industrial Parks: Champions and the Role of Trust	Regional studies	42
45	SCOPUS	2008	(Hoffmann and Busch, 2008)	Corporate carbon performance indicators: Carbon intensity, dependency, exposure, and risk	Journal of Industrial Ecology	12
46	SCOPUS	2008	(Hueseman n and Huesemann , 2007)	Will progress in science and technology avert or accelerate global collapse? A critical analysis and policy recommendations	Environment, Development and Sustainability	10
47	WOS/ SCOPUS	2008	(Kharel and Charmondu sit, 2008)	Eco-efficiency evaluation of iron rod industry in Nepal	Journal of Cleaner Production	16
48	WOS	2008	(Körhönen, 2008)	Reconsidering the economics logic of ecological modernization	Environment and planning a	40
49	SCOPUS	2008	(Mont, 2008)	Innovative approaches to optimising design and use of durable consumer goods	International Journal of Product Development	6
50	WOS	2008	(Muñoz et al., 2008)	Consider a Spherical Man - A Simple Model to Include Human Excretion in Life Cycle Assessment of Food Products	Journal of industrial ecology	12
51	WOS/ SCOPUS	2008	(Ness, 2008)	Sustainable urban infrastructure in China: Towards a Factor 10 improvement in resource productivity through integrated infrastructure systems	International Journal of sustainable development and world ecology	15
52	WOS/ SCOPUS	2008	(Park et al., 2008)	Strategies for sustainable development of industrial park in Ulsan, South Korea - From spontaneous evolution to systematic expansion of industrial symbiosis	Journal of environmental management	87
53	WOS	2009	(Adamides and Mouzakitis, 2009)	Industrial ecosystems as technological niches	Journal of Cleaner Production	17

54	WOS/ SCOPUS	2009	(Andrews and deVault, 2009)	Green Niche Market Development	Journal of industrial ecology	13
55	WOS	2009	(Cao et al., 2009)	Applying agent-based modeling to the evolution of eco-industrial systems	Ecological economics	68
56	WOS	2009	(Deutz, 2009)	Producer responsibility in a sustainable development context: ecological modernization or industrial ecology?	Geographical journal	175
57	WOS/ SCOPUS	2009	(Eckelman and Chertow, 2009)	Using Material Flow Analysis to Illuminate Long-Term Waste Management Solutions in Oahu, Hawaii	Journal of industrial ecology	13
58	WOS/ SCOPUS	2009	(Geng et al., 2009a)	Assessment of the National Eco-Industrial Park Standard for Promoting Industrial Symbiosis in China	Journal of industrial ecology	13
59	SCOPUS	2009	(Körhönen and Baumgartner, 2009)	The industrial ecosystem balanced scorecard	International Journal of Innovation and Sustainable Development	4
60	WOS/ SCOPUS	2009	(Niza et al., 2009)	Urban Metabolism Methodological Advances in Urban Material Flow Accounting Based on the Lisbon Case Study	Journal of industrial ecology	13
61	WOS/ SCOPUS	2009	(van Berkel et al., 2009)	Industrial and urban symbiosis in Japan: Analysis of the Eco-Town program 1997-2006	Journal of environmental management	90
62	WOS/ SCOPUS	2010	(Barberio et al., 2010)	Use of Incinerator Bottom Ash for Frit Production	Journal of industrial ecology	14
63	WOS	2010	(Carrillo-Hermosilla et al., 2010)	Diversity of eco-innovations: Reflections from selected case studies	Journal of Cleaner Production	18
64	WOS/ SCOPUS	2010	(del Río et al., 2010)	Policy Strategies to Promote Eco-Innovation	Journal of industrial ecology	14
65	WOS/ SCOPUS	2010	(Erdmann and Hilty, 2010)	Scenario Analysis Exploring the Macroeconomic Impacts of Information and Communication Technologies on Greenhouse Gas Emissions	Journal of industrial ecology	14
66	WOS/ SCOPUS	2010	(Geng et al., 2010a)	Evaluation of innovative municipal solid waste management through urban symbiosis: a case study of Kawasaki	Journal of Cleaner Production	18
67	WOS	2010	(Geng et al., 2010b)	Regional initiatives on promoting cleaner production in China: a case of Liaoning	Journal of Cleaner Production	90

68	WOS/ SCOPUS	2010	(Graedel and Cao, 2010)	Metal spectra as indicators of development	Proceedings of the national academy of sciences of the united states of america	107
69	WOS/ SCOPUS	2010	(Heiskanen and Lovio, 2010)	User-Producer Interaction in Housing Energy Innovations	Journal of industrial ecology	14
70	WOS/ SCOPUS	2010	(Kaenzig and Wüstenhag en, 2010)	The Effect of Life Cycle Cost Information on Consumer Investment Decisions Regarding Eco-Innovation	Journal of industrial ecology	14
71	WOS/ SCOPUS	2010	(Tukker et al., 2010)	The Impacts of Household Consumption and Options for Change	Journal of industrial ecology	14
72	WOS/ SCOPUS	2010	(Venkatesh, 2010)	Triple Bottom Line Approach to Individual and Global Sustainability	Problemy ekorozwoju	5
73	WOS	2010	(Zhu et al., 2010)	Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications	Journal of environmental management	91
74	WOS/ SCOPUS	2011	(Albu, 2011)	Business innovation using industrial ecology	Metalurgia international	16
75	WOS	2011	(Baas, 2011)	Planning and Uncovering Industrial Symbiosis: Comparing the Rotterdam and Ostergotland regions	Business strategy and the environment	20
76	WOS	2011	(Barbiroli, 2011)	Economic consequences of the transition process toward green and sustainable economies: costs and advantages	International journal of sustainable development and world ecology	18
77	WOS/ SCOPUS	2011	(Chen et al., 2011)	The potential environmental gains from recycling waste plastics: Simulation of transferring recycling and recovery technologies to Shenyang, China	Waste Manage.	31
78	SCOPUS	2011	(Heyes and Kapur, 2011)	Regulatory attitudes and environmental innovation in a model combining internal and external R&D	Journal of Environmental Economics and Management	61
79	WOS/ SCOPUS	2011	(Köhler et al., 2011)	Prospective Impacts of Electronic Textiles on Recycling and Disposal	Journal of industrial ecology	15
80	WOS/ SCOPUS	2011	(Moreno et al., 2011)	Application of Product Data Technology Standards to LCA Data	Journal of industrial ecology	15
81	WOS/ SCOPUS	2011	(Subhadra, 2011)	Macro-level integrated renewable energy production schemes for sustainable development	Energy policy	39

82	WOS	2012	(Brent et al., 2012)	Mineral Carbonation as the Core of an Industrial Symbiosis for Energy-Intensive Minerals Conversion	Journal of industrial ecology	16
83	WOS/ SCOPUS	2012	(Cerón-Palma et al., 2012)	Barriers and Opportunities Regarding the Implementation of Rooftop Eco.Greenhouses (RTEG) in Mediterranean Cities of Europe	Journal of urban technology	19
84	WOS/ SCOPUS	2012	(Chen et al., 2012)	The Impact of Scale, Recycling Boundary, and Type of Waste on Symbiosis and Recycling	Journal of Industrial Ecology	16
85	WOS/ SCOPUS	2012	(Lombardi and Laybourn, 2012)	Redefining Industrial Symbiosis	Journal of industrial ecology	16
86	WOS/ SCOPUS	2012	(Matus et al., 2012)	Green chemistry and green engineering in China: drivers, policies and barriers to innovation	Journal of Cleaner Production	32
87	WOS/ SCOPUS	2012	(Maurizio Catulli, 2012)	Information and Communication Technology-Enabled Low Carbon Technologies A New Subsector of the Economy?	Journal of industrial ecology	16
88	WOS	2012	(Paquin and Howard-Grenville, 2012)	The Evolution of Facilitated Industrial Symbiosis	Journal of industrial ecology	16
89	SCOPUS	2012	(Raafat et al., 2012)	Semantically-enabled Formalisation to Support and Automate the Application of Industrial Symbiosis	Computer Aided Chemical Engineering	31
90	WOS/ SCOPUS	2012	(Shi et al., 2012)	Toward a Low Carbon-Dematerialization Society Measuring the Materials Demand and CO2 Emissions of Building and Transport Infrastructure Construction in China	Journal of industrial ecology	16
91	WOS	2012	(Simpson, 2012)	Knowledge resources as a mediator of the relationship between recycling pressures and environmental performance	Journal of Cleaner Production	22
92	SCOPUS	2013	(Bergquist et al., 2013)	Command-and-control revisited: Environmental compliance and technological change in Swedish industry 1970-1990	Ecological Economics	85
93	WOS/ SCOPUS	2013	(Chen and Sheu, 2013)	Pursuing extended producer responsibility in the context of EIPs by a Hotelling model	Journal of Cleaner Production	57
94	WOS/ SCOPUS	2013	(Collado-Ruiz and Ostad-Ahmad-Ghorabi, 2013)	Estimating Environmental Behavior Without Performing a Life Cycle Assessment	Journal of industrial ecology	17

95	WOS/ SCOPUS	2013	(Dong et al., 2013b)	Environmental and economic gains of industrial symbiosis for Chinese iron/steel industry: Kawasaki's experience and practice in Liuzhou and Jinan	Journal of Cleaner Production	59
96	SCOPUS	2013	(Grundmann et al., 2013)	Risk-based management of chemicals and products in a circular economy at a global scale- Impacts of the FP7 funded project RISKCYCLE	Environmental Sciences Europe	25
97	WOS/ SCOPUS	2013	(Jones et al., 2013)	Enhanced Landfill Mining in view of multiple resource recovery: a critical review	Journal of Cleaner Production	55
98	WOS	2013	(Pajunen et al., 2013)	The challenge to overcome institutional barriers in the development of industrial residue based novel symbiosis products - Experiences from Finnish process industry	Minerals engineering	46-47
99	WOS/ SCOPUS	2013	(Raafat et al., 2013)	An ontological approach towards enabling processing technologies participation in industrial symbiosis	Computers & chemical engineering	59
100	WOS/ SCOPUS	2013	(Reh, 2013)	Process engineering in circular economy	Particuology	11
101	SCOPUS	2013	(Tonelli et al., 2013)	Sustainable innovation: Eco-development tendencies and Theory of communicative action standpoint	Journal of Technology Management and Innovation	8
102	WOS/ SCOPUS	2013	(Tong and Yan, 2013)	From Legal Transplants to Sustainable Transition Extended Producer Responsibility in Chinese Waste Electrical and Electronic Equipment Management	Journal of industrial ecology	17
103	SCOPUS	2013	(van den Bergh, 2013)	Robert Ayres, ecological economics and industrial ecology	Environmental Innovation and Societal Transitions	9
104	WOS	2013	(Vernay et al., 2013)	Exploring the socio-technical dynamics of systems integration - the case of sewage gas for transport in Stockholm, Sweden	Journal of Cleaner Production	44
105	WOS/ SCOPUS	2013	(Watkins et al., 2013)	Overcoming institutional barriers in the development of novel process industry residue based symbiosis products - Case study at the EU level	Minerals engineering	41
106	WOS	2013	(Zhu and Geng, 2013)	Drivers and barriers of extended supply chain practices for energy saving and emission reduction among Chinese manufacturers	Journal of Cleaner Production	40
107	WOS	2014	(Cerceau et al., 2014)	Implementing industrial ecology in port cities: international overview of case studies and cross-case analysis	Journal of Cleaner Production	74

108	WOS/ SCOPUS	2014	(Dahmus, 2014)	Can Efficiency Improvements Reduce Resource Consumption? A Historical Analysis of Ten Activities	Journal of industrial ecology	18
109	WOS	2014	(Dong et al., 2014)	Uncovering opportunity of low-carbon city promotion with industrial system innovation: Case study on industrial symbiosis projects in China	Energy policy	65
110	SCOPUS	2014	(Fichter and Hintemann, 2014)	Beyond Energy: The Quantities of Materials Present in the Equipment of Data Centers	Journal of Industrial Ecology	18
111	SCOPUS	2014	(Ganapathy et al., 2014)	Influence of eco-innovation on Indian manufacturing sector sustainable performance	International Journal of Sustainable Development and World Ecology	21
112	WOS	2014	(Geng et al., 2014)	Emergy-based assessment on industrial symbiosis: a case of Shenyang Economic and Technological Development Zone	Environmental science and Pollution Research	21
113	WOS/ SCOPUS	2014	(Ioppolo et al., 2014)	Industrial Ecology and Environmental Lean Management: Lights and Shadows	Sustainability	6
114	WOS	2014	(Lemke and Luzio, 2014)	Exploring Green Consumers' Mind-Set toward Green Product Design and Life Cycle Assessment The Case of Skeptical Brazilian and Portuguese Green Consumers	Journal of industrial ecology	18
115	WOS/ SCOPUS	2014	(Lenzen et al., 2014)	Compiling and using input-output frameworks through collaborative virtual laboratories	Science of the total environment	485
116	WOS/ SCOPUS	2014	(Liu et al., 2014)	Analysis of sustainable urban development approaches in China	Habitat international	41
117	WOS/ SCOPUS	2014	(Lucchetti and Arcese, 2014)	Tourism Management and Industrial Ecology: A Theoretical Review	Sustainability	6
118	WOS/ SCOPUS	2014	(Mattiussi et al., 2014)	A decision support system for sustainable energy supply combining multi-objective and multi-attribute analysis: An Australian case study	Decision support systems	57
119	WOS/ SCOPUS	2014	(Mirabella et al., 2014)	Current options for the valorization of food manufacturing waste: a review	Journal of Cleaner Production	65
120	WOS/ SCOPUS	2014	(Park and Chertow, 2014)	Establishing and testing the "reuse potential" indicator for managing wastes as resources	Journal of environmental management	137
121	WOS	2014	(Patala et al., 2014)	Towards a broader perspective on the forms of eco-industrial networks	Journal of Cleaner Production	82

122	WOS/ SCOPUS	2014	(Sanyé-Mengual et al., 2014)	Eco-Designing the Use Phase of Products in Sustainable Manufacturing The Importance of Maintenance and Communication-to-User Strategies	Journal of industrial ecology	18
123	WOS/ SCOPUS	2014	(Short et al., 2014)	From Refining Sugar to Growing Tomatoes Industrial Ecology and Business Model Evolution	Journal of industrial ecology	18
124	WOS	2014	(Simboli et al., 2014)	Analysing the development of Industrial Symbiosis in a motorcycle local industrial network: the role of contextual factors	Journal of Cleaner Production	66
125	WOS/ SCOPUS	2014	(Vivanco et al., 2014)	Using LCA-based Decomposition Analysis to Study the Multidimensional Contribution of Technological Innovation to Environmental Pressures	Journal of industrial ecology	18
126	WOS/ SCOPUS	2014	(Yu et al., 2014).	Process analysis of eco-industrial park development - the case of Tianjin, China	Journal of Cleaner Production	64
127	WOS	2015	(Baas and Hjelm, 2015)	Support your future today: enhancing sustainable transitions by experimenting at academic conferences	Journal of Cleaner Production	98
128	WOS	2015	(Bakshi et al., 2015)	Techno-Ecological Synergy: A Framework for Sustainable Engineering	Environmental science & technology	49
129	WOS	2015	(Birat, 2015)	Life-cycle assessment, resource efficiency and recycling	Metallurgical research & technology	112
130	WOS	2015	(Cecelja et al., 2015)	e-Symbiosis: technology-enabled support for Industrial Symbiosis targeting Small and Medium Enterprises and innovation	Journal of Cleaner Production	98
131	WOS/ SCOPUS	2015	(Corder et al., 2015)	Wealth from metal waste: Translating global knowledge on industrial ecology to metals recycling in Australia	Minerals engineering	76
132	WOS	2015	(Levänen, 2015)	Ending waste by law: institutions and collective learning in the development of industrial recycling in Finland	Journal of Cleaner Production	87
133	WOS/ SCOPUS	2015	(Lopes, 2015)	Engineering biological systems toward a sustainable bioeconomy	Journal of industrial microbiology & biotechnology	42
134	WOS/ SCOPUS	2015	(Mattinen et al., 2015)	Energy Use and Greenhouse Gas Emissions of Air-Source Heat Pump and Innovative Ground-Source Air Heat Pump in a Cold Climate	Journal of industrial ecology	19
135	WOS	2015	(Nguyen and Ye, 2015)	Study and evaluation on sustainable industrial development in the Mekong Delta of Vietnam	Journal of Cleaner Production	86

136	WOS	2015	(Patnaik and Poyyamoli, 2015)	Developing an eco-industrial park in Puducherry region, India - a SWOT analysis	Journal of environmental planning and management	58
137	SCOPUS	2015	(Peralta-Álvarez et al., 2015)	MGE2: A framework for cradle-to-cradle design	DYNA	82
138	WOS/ SCOPUS	2015	(Riding et al., 2015)	Harmonising conflicts between science, regulation, perception and environmental impact: The case of soil conditioners from bioenergy	Environment International	75
139	WOS	2015	(Ruiz Puente et al., 2015)	Industrial symbiosis opportunities for small and medium sized enterprises: preliminary study in the Besaya region (Cantabria, Northern Spain)	Journal of Cleaner Production	87
140	WOS/ SCOPUS	2015	(Silva et al., 2015)	Combined MFA and LCA approach to evaluate the metabolism of service polygons: A case study on a university campus	Resources conservation and recycling	94
141	WOS	2015	(Zhu et al., 2015)	Barriers to Promoting Eco-Industrial Parks Development in China: Perspectives from Senior Officials at National Industrial Parks	Journal of industrial ecology	19

Appendix 2 - “Grey literature” technical contributions

	Source	Year	Title
1	(Bastein et al., 2013)	2013	Opportunities for a circular economy in The Netherlands – TNO Report
2	(Caterpillar, 2015)	2015	Caterpillar Named Finalist for Prestigious Sustainability Honor
3	(Coca-Cola, 2015)	2015	Coca-Cola Enterprises : News : Infineo 2.0 - The first online circular economy platform
4	(EC, 2011a)	2011	Innovation for a sustainable Future - The Eco-innovation Action Plan (Eco-AP)
5	(EC, 2011c)	2011	A resource-efficient Europe – Flagship initiative under the Europe 2020
6	(EC, 2014b)	2014	Progress Report on the Roadmap to a Resource Efficient Europe
7	(EC, 2014c)	2014	The circular economy - Connecting, creating and conserving value
8	(EC, 2014f)	2014	Towards a circular economy: A zero waste programme for Europe
9	(EC, 2014h)	2014	European Resource Efficiency Platform (EREP)
10	(EC, 2015a)	2015	Closing the loop – An EU action Plan for the Circular Economy
11	(EC, 2015b)	2015	Draft Horizon 2020 Work Programme 2016 – 2017 in the area of Cross-cutting activities (Focus Areas)
12	(EC, 2015c)	2015	From niche to norm -Suggestions by the group of experts on a “systemic approach to eco-innovation to achieve a low-carbon, circular economy”
13	(EIO, 2011)	2011	The Eco-Innovation Challenge: Pathways to a resource-efficient Europe.
14	(EIO, 2012)	2012	EIO Methodological Report
15	(EIO, 2013a)	2013	The Eco-Innovation Gap: An economic opportunity for business.
16	(EIO, 2013b)	2013	A systemic perspective on eco-innovation
17	(EMF, 2012)	2012	Towards the Circular Economy: economic and business rationale for an accelerated transition
18	(EMF, 2013)	2013	Towards the Circular Economy: opportunities for the consumer goods sector
19	(EMF, 2014a)	2014	Accelerating the scale-up across global supply chains
20	(EMF, 2014c)	2014	Detailed Calculation Methodology for a Material Circularity Indicator for a Product and Guidance on its Use
21	(EMF, 2015a)	2015	Growth within: A circular economy vision for a competitive Europe
22	(EMF, 2015b)	2015	Delivering the Circular economy: A toolkit for policymakers
23	(FUSION Observatory, 2014)	2014	What does the Circular Economy mean to Small and Medium sized businesses in Europe?
24	(IAU, 2013)	2013	Économie circulaire, écologie industrielle Éléments de réflexion à l’échelle de l’Île-de-France
25	(Mitchell and Morgan, 2015)	2015	Employment and the circular economy: Job creation in a more resource efficient Britain - Green Alliance and WRAP Report
26	(OECD, 2009a)	2009	Sustainable manufacturing and eco-innovation. Framework, practices and measurement. Synthesis report

27	(OECD, 2010a)	2010	Eco-Innovation in Industry: enabling green growth
28	(OECD, 2011c)	2011	Fostering Innovation for Green Growth
29	(OECD, 2011d)	2011	Better Policies to Support Eco-innovation
30	(Philips, 2014)	2014	Rethinking the future. Our transition towards a circular economy
31	(Renault, 2014)	2014	Competitive circular economy
32	(Ricoh, 2013)	2013	Ricoh News | Ricoh becomes member of the Ellen MacArthur Foundation's 'Circular Economy 100'
33	(Rizos et al., 2015)	2015	The Circular Economy: Barriers and Opportunities for SMEs
34	(UNDESA, 2011)	2011	World Economic and Social Survey 2011 - The Great Green Technological Transformation
35	(UNEP, 2011)	2011	Decoupling Natural Resource use and Environmental Impacts from Economic Growth , UNEP, International Resource Panel
36	(UNEP, 2006)	2006	Circular Economy: An alternative model for economic development
37	(van Gansewinkel Groep, 2013)	2013	Sustainability report 2013
38	(Vanner et al., 2014)	2014	Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains
39	(Veolia, 2014)	2014	Making the circular economy
40	(WEF, 2009)	2009	Sustainability for Tomorrow's Consumer
41	(WEF, 2010)	2010	Redesigning Business Value: A Roadmap for Sustainable Consumption
42	(WEF, 2014)	2014	Towards the Circular Economy: Accelerating the scale-up across global supply chains
43	(Wijkman and Skånberg, 2015)	2015	The Circular Economy and Benefits for Society - Interim report by the Club of Rome with support from the MAVA Foundation and the Swedish Association of Recycling Industries

Note: Includes reports and policy papers made by government organisations, "think tank" institutions and private companies.

Appendix 3 - Y02 Applicant Companies

	Applicant Company Denomination	Sector/ Focus areas	Nº of patents	Nº of patents with CE characteristics	Country
1	**Active space technologies actividades aeroespaciais SA**	**Engineering**	**1**	**1**	**PT**
2	**Addvolt SA**	**Energy**	**1**	**1**	**PT**
3	**Advanced Mineral Recovery Technologies (AMRT Ltd.)**	**Recycling Minerals Recovery**	**2**	**1**	**GB**
4	**Aguacure Ltd**	**Waste treatment Recycling**	**1**	**1**	**GB**
5	**Air liquide**	**Industrial gases Chemicals**	**2**	**1**	**FR**
6	Aitchison - Electrical & Computer Engineering	Photonics	1		GB
7	**Allwinmob Lda**	**Energy**	**1**	**1**	**PT**
8	Altoga organizacao gestao e aprendizagem Lda	Information technology and computer service activities	1		PT
9	**Ambisys SA**	**Food and Drink**	**1**	**1**	**PT**
10	Amtrol licensing Inc	Water	1		US
11	**Ao Sol Energias Renováveis**	**Renewable energy**	**5**	**5**	**PT**
12	**Armadilha solar arquitectura**	**Energy Architecture**	**1**	**1**	**PT**
13	**BASF**	**Chemical**	**1**	**1**	**DE**
14	Bial portela & CA SA	Chemical Health	1		PT
15	**Biosafe indústria de reciclagens SA**	**Recycling**	**2**	**2**	**PT**
16	**Biosinkco2 tech Lda**	**Construction**	**1**	**1**	**PT**
17	**Bosch gmbh**	**Engineering Electronic**	**1**	**1**	**DE**
18	C a z soc conf Lda	**Engineering**	1		PT
19	Cantante de matos engenharia	**Construction**	1		PT
20	**Casas em movimento Lda**	**Construction**	**1**	**1**	**PT**

21	Categoria & Rigor - unipessoal Lda	Construction	1	1	PT
22	Ceisa packaging	Plastics Recycling	1	1	FR
23	Chipidea microelectronica SA	Semiconductors Wireless communications Digital media, Electronics	1	1	PT
24	Cimpor Cimentos de Portugal sgps SA	Cement manufacturer	2	2	PT
25	Clearwinds systems SA	Construction	1	1	PT
26	Clever action Lda	Energy Recycling	2	1	PT
27	Cmp-Cimentos maceira e pataias SA	Cement manufacturer	1	1	PT
28	Collares pereira engenharia Unipessoal	Construction Engineering	1	1	PT
29	Corticeira Amorim SA	Raw Materials, Cork Stoppers, Coverings, Cork Composites and Isolations	1	1	PT
30	Cs Coelho da silva SA	Construction	2	2	PT
31	Cuf quimicos industriais SA	Chemical	1		PT
32	Cwj projecto SA	Electronics	1	1	PT
33	D2m energytransit unipessoal Lda	Energy	1	1	PT
34	Domino industria cerâmica SA	Construction	1	1	PT
35	Easypal ag	Engineering	1	1	CH
36	Efacec engenharia SA	Energy	6	3	PT
37	EID-Empresa de Investigação e Desenvolvimento de Electrónica SA	Electronics Communication Software	1	1	PT
38	EIDT-engenharia, inovacao e desenvolvimento technologigo Ltd	Construction	1	1	SA
39	Elenco de qualidade equipamentos de controlo unipessoal Lda	Quality equipment control	1	1	PT

40	**Energia Própria, SA**	**Energy**	**1**	**1**	**PT**
41	**Energia Solar Climatização Lda**	**Energy**	**1**	**1**	**PT**
42	**Eneida wireless & sensors SA**	**Electronics** **Energy** **Automation** **Telecommunications**	**1**	**1**	**PT**
43	**Enerwave producao de energa Lda**	**Energy**	**1**	**1**	**PT**
44	**Enforce engenharia da energia SA**	**Energy**	**1**	**1**	**PT**
45	Eva estudos com viabilidade ambiental	**Engineering**	1		PT
46	**Felino fundição de construções mecânicas SA**	**Construction**	**1**	**1**	**PT**
47	**Finertec Fuels Centro Lda**	**Energy**	**1**	**1**	**PT**
48	Foodfarmbiz Lda	Agricultural equipment	1		PT
49	Fradical fabrica de transformação de Cal	Organic Mortars	1		PT
50	**Frezite equipamentos energéticos & ambiente Lda**	**Construction**	**1**	**1**	**PT**
51	**Fusa consultores e investimentos unipessoal Lda**	**Consulting**	**1**	**1**	**PT**
52	**Gröne consulting Lda**	**Construction** **Engineering**	**1**	**1**	**PT**
53	Hcl cleantech Ltd	Biofuel	1		IL
54	Hovione farmaciencia SA	Chemical Health	1		PT
55	**Iberfer equipamentos e construcoes técnicas SA**	**Construction**	**1**	**1**	**PT**
56	**Ifp energies nouvelles**	**Energy**	**2**	**1**	**FR**
57	**Iungo energy solutions unipessoal Lda**	**Energy**	**1**	**1**	**PT**
58	**JVCO estudo e projecto de engenharia em energia e ambiente**	**Engineering** **Construction**	**1**	**1**	**PT**
59	Joao de deus & filhos SA	Automotive Thermal System Production	1		PT
60	**Labicer-Laboratório Industrial Cerâmico SA**	**Construction**	**1**	**1**	**PT**
61	Light prescriptions innovators	Nonimaging optics industry	1		US

62	**Martifer equipamentos para energia SA**	**Construction Energy**	**3**	**3**	**PT**
63	Martifer solar SA	Energy	1		PT
64	**MBE SOTKON**	**Recycling**	**1**	**1**	**ES**
65	Mecalbi actividades de engenharia	Engineering	1		PT
66	**Mecanova projectos de mecânica Lda**	**Engineering**	**1**	**1**	**PT**
67	**Methanpetrol Lda**	**Energy**	**1**	**1**	**PT**
68	Minorca fabricante de maquinas industriais Lda	Industrial Machinery Manufacturer	1		PT
69	**Modeling solutions Lda**	**Construction**	**1**	**1**	**PT**
70	Moletherm holding ag	Consulting	6		CH
71	Nokia siemens networks	Telecommunications	1		FI
72	Omnidea Lda	Wind Energy systems	1		PT
73	**Panty candy limited**	**Clothing**	**1**	**1**	**GB**
74	**Plasdan Projectos Industriais para a Indústria de plásticos**	**Plastics**	**2**	**2**	**PT**
75	Portela & CA SA	Chemical Health	1		PT
76	**Prior fabrica de plasticos Lda**	**Plastics**	**1**	**1**	**PT**
77	PEEHR - Produtora de energia eléctrica por hidro-reação, unipessoal, Lda	Energy	1		PT
78	Proenol - Indústria Biotecnológica Lda	Biotechnology	1		PT
79	**Protenerg Proteínas alimentares**	**Food**	**1**	**1**	**PT**
80	**Qualitas lab**	**Chemical**	**1**	**1**	**PT**
81	**Quinta dos Inglesinhos Agro-indústria LDA**	**Food**	**1**	**1**	**PT**
82	Quizcamp-fabrico e comércio produtos alimentares SA	Food	1		PT
83	Reef power investigacao e desenvolvimento Lda	Energy	1		PT
84	**Revigrés - indústria de revestimentos de grés Lda**	**Construction**	**2**	**2**	**PT**
85	**Rve sol - soluçoes de energia rural Lda**	**Energy**	**1**	**1**	**PT**

86	Saint gobain	Construction	1		FR
87	Sakproject internat SA	Manufacture of protective and safety equipment	1		PT
88	**Schneider electric automation**	**Electronics Industrial Automation and Control**	**6**	**6**	**DE**
89	**Sea for life Lda**	**Clean technologies**	**4**	**4**	**PT**
90	**Secil companhia geral de cal e cimento SA**	Cement manufacturer	**5**	**4**	**PT**
91	Sensis investigacao e desenvolvimento em engenharia quimica Lda	Engineering	1		PT
92	Servotrol sistemas de comando	Automatic Command Systems	1		PT
93	**SGC - SGPS SA**	**Communication**	**1**	**1**	**PT**
94	Siemens ag	Electrification, Automation Digitalization	1		DE
95	Simoldes plasticos SA	Plastic	1		PT
96	SITAF Investigação e desenvolvimento de tecnologias avançadas para a formação, SA	Engineering	1		PT
97	**Sociedade Nacional De Cortiças SA**	**Cork**	**1**	**1**	**PT**
98	Sociedade portuguesa do ar liquido Lda	Industrial gases Chemicals	1		PT
99	**Solarcar Lda**	**Electric Mobility**	**1**	**1**	**PT**
100	Solchemar - Fabrico e Comercialização de Produtos Químicos	Manufacture and Marketing of Chemicals	1		PT
101	Sonergil	Energy	1		PT
102	**SRE Soluções racionais de engenharia, SA**	**Energy Engineering**	**1**	**1**	**PT**
103	**STI - Sistemas e Técnicas Industriais**	**Engineering Food**	**1**	**1**	**PT**
104	SUN CO Companhia de Energia Solar	Energy	1		PT
105	**Sun'R**	**Energy**	**1**	**1**	**FR**

106	**Sun Yupin**	**Energy** **Illumination**	**1**	**1**	**US**
107	**Synopsys Inc**	**Electronics**	**1**	**1**	**US**
108	**T&T multielétrica Lda**	**Energy**	**1**	**1**	**PT**
109	**Tate and Lyle**	**Food**	**3**	**3**	**US**
110	**Tecnia processos e equipamento**	**Industrial and Environmental Equipment**	**2**	**2**	**PT**
111	**Total SA**	**Energy**	**1**	**1**	**FR**
112	Ultimate power Lda	**Energy**	1		PT
113	**VASCONCEPT - Engineering Solutions Development**	**Engineering**	**1**	**1**	**PT**
114	Vertequip equipamentos e trabalhos verticais Lda	Construction	1		PT
115	**Viris natura e ambiente SA**	**Construction**	**1**	**1**	**PT**
116	**Waydip - Energia e Ambiente Lda**	**Energy**	**1**	**1**	**PT**
117	Wobben properties Gmbh	Technologies of Information	1		DE
118	Ydreams informática SA	Technologies of Information	1		PT
119	**Youniverse unipipessoal Lda**	**Communication**	**1**	**1**	**PT**
120	Zeneca Ltd	Chemical Health	1		GB
121	ZTE corporation	Telecommunications	1		CN
122	ZTE portugal projectos de telecomunicacoes unipessoal Lda	Telecommunications	1		PT

Note: Y02 Applicant Companies – In Bold applicant companies of Y02 patents with CE characteristics; underlined cases where there are more than 1 Y02 with CE characteristics

Appendix 4 - Portuguese Applicant Companies with more than one patent

Companies	Priority nº	Priority date	Patent title	Partnerships	
				With other companies	With Universities
AO SOL ENERGIA RENOVAVEIS	PT200801 04168 20080902	2008	Cpc type solar collector with evacuated tubes		
	PT200801 04084 20080602	2008	Quasi-stationary solar concentrators with vacuum tubes or fins and non stationary optics		
	PT200801 03939 20080122	2008	Augmenting elements for façade solar collectors		
	PT200801 04133 20080717	2008	Solar concentrating collector of the cpc type with an improved absorbing cavity, without thermal shorts and optical losses		
	PT200401 03182 20040809	2004	Colectores do tipo cpc para concentração sobre absorventes imersos em líquidos de índice de refracção n		
BIOSAFE INDÚSTRIA DE RECICLAGENS SA	PT201201 06557 20120928	2012	Composite profile for solar collector, method for producing and using same		
	WO2012P T00023 20120628	2012	Composite material of rubber granulates from recycled used tires in a polymer matrix		
CIMPOR CIMENTOS DE PORTUGAL SGPS SA	WO2015P T00006 20150119	2015	Amorphous low-calcium content silicate hydraulic binders and methods for their manufacturing		Instituto Superior Técnico
	WO2015P T00005 20150119	2015	Dendritic belite based hydraulic binders and methods for their manufacturing		Instituto Superior Técnico
CLEVER ACTION LDA	PT2014010 8117 20141224	2014	Unidade de plantação para indução e gestão extemporâneas dos tempos de ciclos biológicos de plantas em cultura, em ambiente controlado		
	WO2010P T00064 20101210	2010	Hanging planting device		
CS COELHO DA SILVA SA	PT201000 10588U 20100614	2010	Processo para colocação de painéis solares térmicos		
	WO2010P T00063 20101210	2010	Ceramic photovoltaic linings, in particular wall, roof and mosaic tiles, and method for manufacturing same	REVIGRÉS - Indústria De Revestimentos De Grés Lda; Domino industria cerâmica SA; Viris natura	Universidade do Minho; Universidade Nova de Lisboa; CENIMAT; INETI; CTCV; ADENE

EFACEC ENGENHARIA SA	PT20140107918 20140925	2014	Wall mountable dc electric vehicle charger
	PT20130107187 20130925 WO2014IB64806 20140924	2013	Catalytic transparent electrode consisting of graphene film and application on metal nanoparticles and a method for preparation and respective usages
	PT20130106849 20130325	**2013**	**Method of treating leachate, phototreatment reactors and respective use**
	WO2012IB51376 20120322 PT20110105578 20110322 PT20110105579 20110322	**2011**	**Substrate and electrode for solar cells and the corresponding manufacturing process**
	PT20110105612 20110404	2011	Catalytic and transparent electrode of graphene, preparation method and applications thereof
	PT20100104996 20100309 WO2011IB50945 20110307	**2010**	**Dye-sensitized solar cells**
MARTIFER EQUIPAMENTO ENERGIA SA	**PT20080103926 20080110**	**2008**	**Device for wave energy extraction**
	PT20070103869 20071029	**2007**	**Dispositivo de extracção de energia das ondas através do movimento relativo entre dois corpos excitados em oposição de fase**
	PT20050103270 20050502	**2005**	**Energy conversion/inversion system**
MARTIFER SOLAR SA	PT20110105511 20110201	2011	Peça plástica para sistema de integração de módulo fotovoltaico
PLASDAN PROJECTOS	**PT20080104109 20080623**	**2008**	**Caixa multifuncional modular, para colectores solares**
	PT20060103471 20060505	**2006**	**Distribuidor hidraulico multifuncional termoplástico com aplicação em paineis solares**

REVIGRÉS - INDÚSTRIA DE REVESTIMENTOS DE GRÉS LDA	**PT20150108603 20150629 PT20150108625 20150630**	**2015**	**Coated ceramic plate, coupling elements for pavements, and uses thereof**		**CENTI - Centro de nanotecnologia e materiais técnicos funcionais e inteligentes)**
	WO2010PT00063 20101210	**2010**	**Ceramic photovoltaic linings, in particular wall, roof and mosaic tiles, and method for manufacturing same**	**CS Coelho da silva SA; Domino industria cerâmica SA; Viris natura e ambiente SA**	**Universidade do Minho; Universidade Nova de Lisboa; CENIMA; INETI; CTCV; ADENE**
SEA FOR LIFE LDA	**PT20120106113 20120126**	**2012**	**Turbina de eixo vertical para aproveitamento directo da energia das ondas**		
	WO2010PT00044 20101015	**2010**	**System for the production of useful energy from sea waves**		
	WO2009PT00002 20090108	**2009**	**Device for generating energy from the motion of sea waves**		
	PT20070103911 20071227	**2007**	**Apparatus for extracting energy from the movement of structures**		
SECIL COMPANHIA GERAL DE CAL E CIMENTO SA	**PT20150108290 20150317**	**2015**	**Method for producing a low-carbon clinker**		
	PT20120106403 20120625	**2012**	**Portland cement, wood particles and light weight aggregates-based composite panel, reinforced with polyvinyl alcohol fibers**		
	US201314063814 20131025 PT20110106007 20111116 US201213678859 20121116	**2011**	**Cementitious binders and wood particles-based incombustible coloured composite panel with structural high performance**		
	PT20110105937 20111017	**2011**	**Lightweight mortar prepared with cork granulate**		
	PT20110105666 20110429	2011	White or coloured, dry, predosed and self-compactable concrete of quick setting with architectural high performances		
	WO2010PT00064 20101210	2010	Hanging planting device		
TECNIA PROCESSOS E EQUIPAMENTO	**WO2006PT00007 20060310**	**2006**	**Biological process for wastewater treatment**		
	PT20050103366 20051010	**2005**	**Jet loop wastewater treatment system**		

Note: Portuguese Applicant Companies with more than one Y02 patent – In Bold applicant companies of Y02 patents with CE characteristics

Appendix 5 - Y02 Applicant Universities – Overall

	University Applicant Denomination	Nº of patents	Nº of patents with CE characteristics	Country
1	**Aarhus Univ.**	**1**	**1**	**DK**
2	**ADENE - Agência para a Energia**	**1**	**1**	**PT**
3	**Centro Tecnológico do Calçado**	**1**	**1**	**PT**
4	**CENTI - Centro de Nanotecnologia e materiais técnicos funcionais e inteligentes**	**2**	**1**	**PT**
5	CITEVE – Centro Tecnológico das indústrias têxtil e do vestuário de Portugal	1		PT
6	**CONICET Conselho Nacional de Pesquisas Científicas e Técnicas**	**1**	**1**	**AR**
7	**CTCV - Centro Tecnológico da Cerâmica e do Vidro**	**1**	**1**	**PT**
8	Glasgow University	1		GB
9	**iBET - Instituto de Biologia Experimental e Tecnológica**	**3**	**1**	**PT**
10	**INETI Instituto Nacional Engenharia Tecnologia e Inovação IP**	**2**	**<u>2</u>**	**PT**
11	**INL - Laboratório Ibérico Internacional de Nanotecnologia**	**2**	**<u>2</u>**	**PT**
12	**Instituto Nacional Engenharia Tecnologia Industrial**	**4**	**<u>2</u>**	**PT**
13	**Instituto Politécnico de Beja**	**1**	**1**	**PT**
14	**Instituto Politécnico de Leiria**	**3**	**<u>2</u>**	**PT**
15	**Instituto Politécnico de Setúbal**	**3**	**<u>2</u>**	**PT**
16	**Instituto Superior Agronomia**	**1**	**1**	**PT**
17	**Instituto Superior de Engenharia de Lisboa**	**1**		**PT**
18	**<u>Instituto Superior Técnico</u>**	**29**	**<u>18</u>**	**PT**
19	**Instituto Tecnológico e nuclear**	**1**	**1**	**PT**
20	**Laboratório Nacional de Energia e Geologia**	**4**	**1**	**PT**
21	**Univ. Nac. de La Plata**	**1**	**1**	**AR**
22	**Univ. Poitiers**	**1**	**1**	**FR**
23	**Universidade da Beira Interior**	**3**	**<u>3</u>**	**PT**
24	**Universidade da Extremadura**	**1**	**1**	**ES**
25	**<u>Universidade de Aveiro</u>**	**11**	**<u>10</u>**	**PT**
26	**Universidade de Coimbra**	**3**	**<u>2</u>**	**PT**
27	**Universidade de Lisboa**	**1**	**1**	**PT**
28	Universidade de Lisboa - Fundação da Faculdade de Ciências	1		PT
29	**<u>Universidade de Trás-os-Montes e Alto Douro</u>**	**6**	**<u>5</u>**	**PT**
30	**<u>Universidade do Algarve</u>**	**4**	**<u>3</u>**	**PT**
31	**<u>Universidade do Minho</u>**	**6**	**<u>6</u>**	**PT**
32	**<u>Universidade do Porto</u>**	**9**	**<u>5</u>**	**PT**
33	Universidade do Porto - Faculdade de Engenharia	1		PT
34	Universidade do Porto - Faculdade de Ciencias	1		PT
35	**<u>Universidade Nova de Lisboa</u>**	**8**	**<u>5</u>**	**PT**
36	**Universidade Nova de Lisboa - Faculdade de Ciências e Tecnologia**	**3**	**1**	**PT**

37	Universidade Nova de Lisboa - Departamento de Quimica	1		PT
38	**Universidade Nova de Lisboa - Centro de investigação em materiais (CENIMAT)**	**2**	**1**	**PT**
39	**Universidade Técnica de Lisboa - Faculdade de Arquitetura**	**1**	**1**	**PT**

Note: Y02 Applicant Universities – In Bold applicant companies of Y02 patents with CE characteristics; underlined cases where there are more than 1 Y02 with CE characteristics

Appendix 6 - Portuguese Applicant Universities with more than one patent

Universities / investigation centres	Priority number	Priority date	Patent title	Partnerships: With other universities/ investigation centres	Partnerships: With Companies
CENTI – Centro de Nanotecnologia e materiais técnicos funcionais e inteligentes	**PT201501 08603 20150629 PT201501 08625 20150630**	**2015**	**Coated ceramic plate, coupling elements for pavements, and uses thereof**		**REVIGRÉS**
	EP201501 69245 20150526	2015	Polymeric multi-layered injection-moulded article with an electric circuit, production method thereof	CITEVE Centro Tecnologico das indústrias têxtil e do vestuário de Portugal	Simoldes plasticos SA
iBET- Instituto de Biologia Experimental e Tecnológica	PT200401 03143 20040608	2004	Clean osmium-catalyzed asymmetric dihydroxylation and aminohydroxylation of olefins in ionic liquids followed by supercritical co2 product recovery	Universidade Nova de Lisboa - Departamento de Quimica	Solchemar - Fabrico e Comercialização de Produtos Químicos
	PT199901 02385 19991206 WO2000P T00012 20001204	1999	Treatment of aqueous media containing electrically charged compounds		
	PT199901 02321 19990611	1999	Hidrogenacao de pineno em meio supercritico		
INETI Instituto Nacional Engenharia Tecnologia e Inovação IP	WO2010P T00063 20101210	2010	Ceramic photovoltaic linings, in particular wall, roof and mosaic tiles, and method for manufacturing same	Universidade Nova de Lisboa; CENIMAT; Universidade do Minho; CTCV; ADENE	REVIGRÉS; CS Coelho da silva SA; Domino industria cerâmica SA; Viris natura e ambiente SA;
	PT199900 09559U 19990922	1999	Bioreactor aerobio		
INL - Laboratório Ibérico Internacional de Nano-tecnologia	EP201501 74105 20150626	2015	A solar cell module		
	EP201501 63195 20150410	2015	A material structure for a solar cell, a solar cell and a method for manufacturing a material structure		

Instituto Nacional Engenharia Tecnologia Industrial	PT200301 03055 20031222	2003	Set of solid supports for toxic metal ions removal from aqueous media includes ligands giving high sequestration capacity for e.g. Actinodes	Instituto Superior Técnico	
	PT199901 02331 19990709	1999	Procedure for complete recovery of iron (iii) uses (2-ethyl hexyl) methyl amino phosphonic acid from aqueous media of high acidity		
	EP199709 10290 19970915 WO1997E P05042 19970915 EP199601 15628 19960930	1996	Use of hydrocarbon-soluble aminomethylenephosphonic acid derivatives for the solvent extraction of metal ions from aqueous solutions		BASF AG [DE]
	PT199100 98179 19910702	1991	Sight (viewing) system for an automatic machine for the production of cork-bark stoppers		EID-Empresa de Investigação e Desenvolvimento de Electrónica SA; Mecanova projectos de mecânica Lda
Instituto Politécnico de Leiria	PT201201 06081 20120104	2012	Dispositivo modular de geração de energia eléctrica a partir de recursos hídricos.		
	PT200901 04863 20091209	2009	Variable geometry air intake system for internal combustion engines		
	PT200901 04472 20090325	2009	Máquina de cortar relva automática movida a energia solar, com reservatório e aparador de cantos		
Instituto Politécnico de Setúbal	PT201301 07173 20130920	2013	Argamassa de cal hidráulica, seu processo de obtenção e respectiva utilização		
	PT201201 06470 20120727 WO2013P T00049 20130726	2012	Electrodeposition process of nickel-cobalt coatings with dendritic structure	Instituto Superior Técnico ; Instituto Superior de Engenharia de Lisboa	
	PT201201 06673 20121129	2012	Processo de inibição da atividade microbiana de biomassa e sua utilização na determinação dos potenciais de biodescoloração e de adsorção de corantes azo	Instituto Superior Técnico	

Instituto Superior Técnico	WO2015PT00006 20150119	2015	Amorphous low-calcium content silicate hydraulic binders and methods for their manufacturing		Cimpor Cimentos de Portugal sgps SA
	WO2015PT00005 20150119	2015	Dendritic belite based hydraulic binders and methods for their manufacturing		Cimpor Cimentos de Portugal sgps SA
	PT20140107816 20140731	2014	Simplified process for preparing electrolyte for vanadium redox batteries		
	WO2014PT00033 20140515 PT20130106943 20130516	2013	Air turbine for applications in wave energy conversion		
	PT20130107151 20130911	2013	Process for the removal and recovery of heavy metals from liquid effluents		
	PT20120106470 20120727 WO2013PT00049 20130726	2012	Electrodeposition process of nickel-cobalt coatings with dendritic structure	Instituto Politécnico de Setúbal; Instituto Superior de Engenharia de Lisboa	
	PT20120011028U 20120628	2012	Estrutura tubular oca para dispositivos para conversão de energia das ondas do tipo coluna de água oscilante flutuante	Laboratório Nacional de Energia e Geologia	
	PT20120106673 20121129	2012	Processo de inibição da atividade microbiana de biomassa e sua utilização na determinação dos potenciais de biodescoloração e de adsorção de corantes azo	Instituto Politécnico de Setúbal	
	PT20110010975U 20111221	2011	Seguidor solar de baixo perfil		
	PT20110105634 20110419	2011	Processo para a preparação de biarilos por reacções de suzuki-miyaura em meio de dióxido de carbono supercrítico, catalisadas por complexos de paládio(ii) com oxadiazolinas e cetoiminas		
	PT20100104972 20100219	2010	Turbine with radial inlet and outlet rotor for use in bidirectional flows		
	PT20100105368 20101108	2010	Tanque flutuante assimétrico conversor de energia das ondas		
	PT20100105171 20100624	2010	Dispositivo flutuante de coluna de água oscilante para conversão da energia das ondas		

Instituto Superior Técnico (Cont.)	PT200901 04885 20091215	2009	Instalação de aproveitamento de energia das ondas
	PT200901 04494 20090406	2009	Integrated process of filtration to dry brewer's spent grain
	PT200901 04348 20090121	2009	Utilização de painéis solares para alimentação do ciclo de refrigeração, nomeadamente de geleiras/malas térmicas
	PT200801 04150 20080731 WO2008P T00037 20080926	2008	Process for covering rubber particles with a polymeric film and covered rubber granulates obtained by this process
	PT200801 04141 20080728	2008	Sincronizador óptimo predictivo de quadratura de fase
	PT200801 04177 20080919	2008	Novo dispositivo para aproveitar o movimento oscilatório relativo de dois corpos, aplicável à extracção de energia das ondas
	PT200801 04034 20080426	2008	Sistema para aquecimento e manutenção de temperatura em panelas de fondue
	PT200701 03640 20070118 WO2008P T00003 20080117	2007	Method for the conversion, under mild conditions and in aqueous medium, of gaseous and liquid alkanes into carboxylic acids
	PT200701 03786 20070713 PT200900 10440U 20090511	2007	Sistema integrado de captação de energia solar nas linhas de caminho de ferro
	PT200701 0	2007	Dispositivo para aproveitar o movimento oscilatório relativo de dois corpos, aplicável a sistemas de aproveitamento de energia das ondas
	3803 20070803		
	PT200701 03797 20070724	2007	Recepiente e método para conservar bebidas a temperaturas constante usando uma caixa de ar
	PT200701 03755 20070531	2007	Método de cálculo de emissões específicas de poluentes em sistemas de combustão
	PT200701 03728 20070504	2007	Embarcação para actividades em zonas ambientalmente sensíveis com sistema híbrido de propulsão eléctrica baseado

Instituto Superior Técnico (Cont.)			em pilha de combustível a hidrogénio e energia fotovoltaica.		
	PT200701 03708 20070404	2007	Sistema integrado de captação e armazenamento de energia solar para aquecimento de água		
	PT200501 03406 20051221	2005	Injection of sequestration carbon dioxide in mining comprises aid to natural gas extraction	Universidade do Porto - Faculdade de Ciencias	
	PT200301 03055 20031222	2003	Set of solid supports for toxic metal ions removal from aqueous media includes ligands giving high sequestration capacity for e.g. Actinodes	Instituto Nacional Engenharia Tecnologia Industrial	
Laboratório Nacional de Energia e Geologia	PT201401 07482 20140226 WO2015I B51440 20150226	2014	A solid electrolyte glass for lithium or sodium ions conduction	Universidade do Porto	
	PT201200 11028U 20120628	2012	Estrutura tubular oca para dispositivos para conversão de energia das ondas do tipo coluna de água oscilante flutuante	Instituto Superior Técnico	
	PT201201 06418 20120629	2012	Process for manufacturing a solid oxide fuel cell electrolyte using microwave sintering	Universidade de Coimbra	
	PT201101 05738 20110531	2011	Consórcio microbiano adaptado para optimização da conversão de substratos orgânicos inibidores/tóxicos por digestão anaeróbia		
Universidade da Beira Interior	PT201201 06607 20121030	2012	Método de controlo de acesso para rede de sensores com suporte para ipv6	Universidade de Aveiro	
	PT200801 04146 20080728	2008	Aerogerador por superfícies sustentadoras em voo cativo		
	PT200701 03812 20070822	2007	Aquatic system for energy storage in the form of compressed air		
Universidade de Aveiro	PT201501 08391 20150421	2015	Modular façade or covering element with solar energy recovery for water heating, air conditioning and ventilation		T&T multielétrica Lda
	PT201201 06607 20121030	2012	Método de controlo de acesso para rede de sensores com suporte para ipv		
	PT201001 05253 20100816	2010	System for using tidal energy for compressing air to drive aerophones		
	PT200901 04869 20091210	2009	Photovoltaic modules and manufacturing process - interconnection of dye-sensitized solar cells		Energia Solar Climatizaçã o Lda
	PT091048 61	2009	Ceramics produced from solid waste incineration bottom ash	Universidade Nova de	

Universidade de Aveiro (Cont.)	20091207 WO2009IB55671 20091210			Lisboa
	PT20070103916 20071228	2007	Artefactos à base de resíduos industriais inertes e de argilas ou sub-produtos argilosos, processo para a sua obtenção e respectivas utilizações em construção civil.	Universidade de Trás-os-Montes e Alto Douro
	PT20060103631 20061229	2006	Cimento belítico fabricado exclusivamente a partir de lamas de anodização de alumínio, lamas de estações de tratamento de água potável, lamas de corte de mármore e areia de fundição	
	PT20060103624 20061227	2006	Process for the production of mixed-metal-oxide inorganic pigments from industrial wastes	
	PT20060103540 20060726	2006	Pigmento cerâmico azul-turquesa isento de cobalto, vanádio e zircónio, contendo lama de cromagem/niquelagem	
	PT20050103268 20050427	2005	Slurry is formed from granite rock cutting process and from drinking water filtration and treatment and is presented as light aggregate	
	PT20050103263 20050420	2005	Slurry generated in process of filtration of water is used as additive in work activity of mortar employed for coating or facing operations	
Universidade de Coimbra	PT20130107286 20131112 PT20130107287 20131112 WO2014PT00066 20141111	2014	Artificial coastal-protection reef with energy generation unit with or without direct contact with seawater	
	PT20120106418 20120629	2012	Process for manufacturing a solid oxide fuel cell electrolyte using microwave sintering	Laboratório Nacional de Energia e Geologia
	AR2009P102570 20090707	2009	Fermented product based on milk whey permeate: production processes and uses	Universidade Nacional de la Plata [AR]; Conselho Nacional de Investigações Científicas e Técnicas (CONICET)

Universidade de Lisboa	PT201201 06263 20120419	2012	Colector solar térmico transparente de baixo custo acoplável à superfície frontal de um módulo fotovoltaico padrão	
Universidade de Lisboa - Fundação da Faculdade de Ciências	PT200501 03331 20050805	2005	Expression of an active carrier from xylose in genetically modified saccharomyces cerevisiae	
Universidade de Trás-os-Montes e Alto Douro	PT201001 05275 20100831	2010	Method and installation for the industrial production of blocks, tablets and granulates from plant waste	
	PT200801 03923 20080107 WO2009P T00001 20090105	2008	Method and device for measuring solar irradiance using a photovoltaic panel	
	PT200701 03916 20071228	2007	Artefactos à base de resíduos industriais inertes e de argilas ou sub-produtos argilosos, processo para a sua obtenção e respectivas utilizações em construção civil.	Universidade de Aveiro
	PT200701 03739 20070511	2007	Process for biomass production from residue and industrial effluents, in particular from timber, cork and cellulose industries	
	PT200701 03738 20070511	2007	Processo biológico aeróbio de tratamento de efluentes agro-industriais com elevado teor em compostos aromáticos baseado na aplicação de microrganismos da espécie candida oleophila	
	PT200601 03470 20060428	2006	A process for the treatment and recovery of residues and effluents from olive oil production units through the utilisation and reprocessing of cork industry waste	
Universidade do Algarve	PT201401 07498 20140307	2014	Colector vertical com vidro exterior em zigue-zague e tubos com dimensões diferenciadas transparentes.	
	PT201401 07491 20140228	2014	Colector termoeléctrico equipado com um sistema multi-tubagens e canal transparentes	
	PT201301 06970 20130528	2013	Colector multicanal com fluxo controlado nas diferentes passagens	
	PT200901 04590 20090525	2009	Colector solar para aquecimento de fluído térmico com duplo circuito integrado	

Universidade do Minho	PT201001 05057 20100419	2010	Processo para obtenção de etanol a partir da borra de café		
	PT201001 05128	2010	Apparatus for the retention of (bio)solids and a method for		Ambisys SA
	20100519		the treatment of a waste material using said apparatus		
	WO2010P T00063 20101210	2010	Ceramic photovoltaic linings, in particular wall, roof and mosaic tiles, and method for manufacturing same	Universidade Nova de Lisboa; CENIMAT; INETI; CTCV; ADENE	REVIGRÉS ; CS Coelho da silva SA; Domino industria cerâmica SA; Viris natura e ambiente SA;
	PT200601 03579 20061006	2006	Sistema de controlo de energia em vãos exteriores de edifícios eco-eficientes		Armadilha solar arquitectura
	PT200501 03332 20050812	2005	Biosorption system produced from biofilms supported on faujasite (fau) zeolite, process obtaining it and its usage for removal of hexavalent chromium (cr (vi))		
	WO2005P T00020 20051118	2005	Novel anaerobic reactor for the removal of long chain fatty acids from fat containing wastewater		
Universidade do Porto	PT201401 07482 20140226 WO2015I B51440 20150226	2014	A solid electrolyte glass for lithium or sodium ions conduction	Laboratório Nacional de Energia e Geologia	
	EP201401 54865 20140212 WO2015D K50029 20150211	2014	A solar rechargeable redox flow cell	Aarhus University [DK]	
	PT201401 08060 20141125	2014	Energy harvesting device for a transport vehicle		ADDVOLT S. A.
	PT201101 05613 20110404	2011	Metal oxide catalysts, preparation methods and applications		
	PT200901 04385 20090216	2009	Sistema hidro-regulável de ventilação da base das paredes para tratamento da humidade ascensional		
	PT200701 03817 20070903	2007	Diferencial electrónico.		

Universidade do Porto (Cont.)	PT200601 03618 20061218 WO2007I B55201 20071218	2006	Smart device for absorbing solar energy and controling sunlight admission		
	PT200601 03615 20061214	2006	Separation column and pressure swing adsorption process for gas purification		
	PT200601 03572 20060927	2006	Air treatment unit, of dehumidification and heating energetically efficient		
Universidade do Porto - Faculdade de Engenharia	PT200501 03368 20051018 WO2006I B53515 20060927	2005	Cumg.sub.2-y li.sub.x alloy for hydrogen storage		
Universidade do Porto - Faculdade de Ciencias	PT200501 03406 20051221	2005	Injection of sequestration carbon dioxide in mining comprises aid to natural gas extraction	Instituto Superior Técnico	
Universidade Nova de Lisboa - Centro de investigação em materiais (CENIMAT)	WO2010P T00063 20101210	2010	Ceramic photovoltaic linings, in particular wall, roof and mosaic tiles, and method for manufacturing same	Universidade Nova de Lisboa; Universidade do Minho; INETI; CTCV; ADENE	REVIGRÉS ; CS Coelho da silva SA; Domino industria cerâmica SA; Viris natura e ambiente SA;
Universidade Nova de Lisboa - Departamento de Quimica	PT200401 03143 20040608	2004	Clean osmium-catalyzed asymmetric dihydroxylation and aminohydroxylation of olefins in ionic liquids followed by supercritical co2 product recovery	iBET- Instituto de Biologia Experimental e Tecnológica	Solchemar - Fabrico e Comercialização de Produtos Químicos
Universidade Nova de Lisboa - Faculdade de Ciências e Tecnologia	PT201501 08203 20150209	2015	Non-intrusive, self-contained and portable device for obtaining energy usage indicators and respective operating procedure		
	WO2009I B54423 20091008 PT200901 04766 20090929	2009	Energy generation and/or storage device based on fibres and thin films		
	WO2009P T00008 20090130 PT200801 03951 20080131	2008	Processing of electric and/or electronic elements on cellulosic material substrates		Ydreams informática SA

Universidade Nova de Lisboa	PT201201 06316 20120517	2012	Modification peripheral system of a building exterior facade	Universidade Tecnica de Lisboa - Faculdade de Arquitectura
	WO2010P T00057 20101209	2010	Mesoscopic optoelectronic devices comprising arrays of semiconductor pillars deposited from a suspension and production method thereof	
	PT200901 04506 20090423	2009	Síntese de biodiesel a partir de borras de café por transesterificação directa com misturas álcool/dióxido de carbono	
	PT091048 61 20091207 WO2009I B55671 20091210	2009	Ceramics produced from solid waste incineration bottom ash	Universidade de Aveiro
	PT200801 03998 20080320 WO2009I B00565 20090320	2008	Method of using cellulose natural, synthetic or composite material simultaneously as carrier and dielectric base in self-sustained field-effect electronic and optoelectronic devices	
	PT200801 04152 20080801	2008	Polyphase motor with variable number of poles	
	PT200701 03780 20070706	2007	Dna sequence encoding a specific l-arabinose transporter, a cdna molecule, a plasmid comprising the said dna sequence, host cell transformed with such plasmid and application thereof	
	PT200601 03577 20061006	2006	Síntese de polímeros solúveis em água, baseados em oxazolinas, em dióxido de carbono supercrítico	

Note: Portuguese Applicant Universities or investigation centres with more than one patent
In Bold applicant universities of Y02 patents with CE characteristics

Appendix 7 - Portuguese Trademarks

APPLICATION NUMBER	APPLICATION YEAR	TRADE MARK NAME	APPLICANT NAME	TRADE MARK OFFICE	DESIGNATED TERRITORY	TRADE MARK TYPE	TYPE OR ACTOR	AUTO-DENOMINATION OF ACTOR	NICE CLASS
000570673	2016	ABO BANCO DE ÓCULOS	A.B.O. - BANCA DE ÓCULOS ASSOCIAÇÃO DE SOLIDARIEDADE	PT	PT	COMBINED	ASSOCIATION	ASSOCIATION	45
000523156	2013	BIO BOARDS	RICARDO MIGUEL MELO MARQUES	PT	PT	COMBINED	ENTREPRENEUR	STARTUP	28
000038528	2016	BLC3 CAMPUS DE TECNOLOGIA E INOVAÇÃO	ASSOCIAÇÃO BLC3 - PLATAFORMA PARA O DESENVOLVIMENTO DA REGIÃO INTERIOR CENTRO	PT	PT	COMBINED	ASSOCIATION	ASSOCIATION	UNDEFINED
013741798	2015	BOOKINGDRIVE.COM	FORTE TRADIÇÃO - GESTÃO IMOBILIÁRIA, S.A.	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,FI,DK,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	WORD	COMPANY	STARTUP	38
000040946	2017	BOOKINGDRIVE.COM	FORTE TRADIÇÃO - GESTÃO IMOBILIÁRIA, S.A.	PT	PT	COMBINED	COMPANY	STARTUP	UNDEFINED
000557169	2015	BOOK IN LOOP	BOOK IN LOOP, LDA.	PT	PT	COMBINED	COMPANY	STARTUP	35,39,41,42
1268988	2015	COOLFARM	COOLFARM	WO	FR,LU,US,RU, ES,NL,BE,GB, DE,IT	FIGURATIVE	COMPANY	STARTUP	42
000031112	2014	COOLFARM	COOLFARM	PT	PT	COMBINED	COMPANY	STARTUP	UNDEFINED

000547315	2015	COOLFARM	COOLFARM	PT	PT	COMBINED	COMPANY	STARTUP	42
000532860	2014	AS PORTUGUESAS	ECOCHIC PORTUGUESAS - FOOTWEAR AND FASHION PRODUCTS	PT	PT	WORD	COMPANY	STARTUP	25
016819096	2017	THE PORTUGUESE	ECOCHIC PORTUGUESAS - FOOTWEAR AND FASHION PRODUCTS	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,C Y,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	WORD	COMPANY	STARTUP	25
016612376	2017	AS PORTUGUESAS	ECOCHIC PORTUGUESAS - FOOTWEAR AND FASHION PRODUCTS	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,C Y,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	WORD	COMPANY	STARTUP	25
000559436	2016	SUGO CORK RUGS	TDCORK TAPETES DECORATIVOS COM CORTIÇA, LDA.	PT	PT	COMBINED	COMPANY	STARTUP	27
000586466	2017	SUGO CORK RUGS	TDCORK TAPETES DECORATIVOS COM CORTIÇA, LDA.	PT	PT	WORD	COMPANY	STARTUP	20, 27
988330	2008	COSTAVERDE	PORCELANAS DA COSTA VERDE, S.A.	WO	JP,LV,LU,LT,G B,HR,RO,TR,N O,HU,BG,FR,B E,DE,MA,FI,D K,IE,AT,CZ,C Y,US,SE,MZ,SI ,AU,SK,IS,IT, MT,PT,PL,UA, RU,EM,CH,GR ,ES,NL,EE,CN	FIGURATIVE	COMPANY	BUSINESS	21
000432998	2008	COSTA VERDE	PORCELANAS DA COSTA VERDE, S.A.	PT	PT	COMBINED	COMPANY	BUSINESS	21

000545315	2015	ECOKALÇADA	ECO SOLUTIONS - COMÉRCIO E INDÚSTRIA, UNIPESSAL, LDA	PT	PT	WORD	COMPANY	BUSINESS	19
000419306	2007	BANCO DE BENS DOADOS	ENTRAJUDA - ASSOCIAÇÃO PARA O APOIO A INSTITUIÇÕES DE SOLIDARIEDADE SOCIAL	PT	PT	COMBINED	ASSOCIATION	ASSOCIATION	45
000558489	2016	FRESH.LAND STRAIGHT FROM THE FARM	FRESH.LAND	PT	PT	COMBINED	COMPANY	STARTUP	31,35
016060972	2016	FRESH.LAND STRAIGHT FROM THE FARM	FRESH.LAND	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,C Y,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	STARTUP	31,32
VA 2016 03031	2016	FRESH.LAND	FRESH.LAND	DK	DK	WORD	COMPANY	STARTUP	29,30,31 ,32,35,4 2
VA 2016 02928	2016	FRESH.LAND	FRESH.LAND	DK	DK	WORD	COMPANY	STARTUP	29,30,31 ,32,35,3 9,42
000488412	2011	GARBAGS 100% RECUP	TÂNIA SOFIA MOREIRA ANSELMO	PT	PT	COMBINED	ENTREPRENEUR	STARTUP	14,18,20 ,25
015517592	2016	GOOD AFTER POUPANÇA SEM PRAZO	GOOD AFTER - SUPERMERCADOS, LDA.	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,C Y,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	BUSINESS	35

000569863	2016	INFINITEBOOK	LOPES & GERKEN, LDA.	PT	PT	COMBINED	COMPANY	STARTUP	16,35
000498384	2012	JINJA	NORMA SUSANA PINTO DA COSTA E SILVA	PT	PT	COMBINED	ENTREPRENEUR	STARTUP	21
013960596	2015	WETRUCK EMPOWER TRUCKS	ADDVOLT, SA	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,FI,DK,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	STARTUP	7,9,12
000532494	2014	WETRUCK - EMPOWER TRUCKS	VANGUARDCHAPTER, LDA.	PT	PT	COMBINED	COMPANY	STARTUP	12
000491806	2011	MOINHO DE CHUVA	FERNANDO RUI RIBEIRO DA SILVA	PT	PT	COMBINED	ENTREPRENEUR	BUSINESS	16
000545719	2015	MONVERDE WINE EXPERIENCE HOTEL	QUINTA DA LIXA - SOCIEDADE TURISMO, UNIPESSOAL LDA.	PT	PT	WORD	COMPANY	BUSINESS	43
000522404	2013	NAE - FASHION WITH COMPASSION	NAE - COMÉRCIO E DISTRIBUIÇÃO DE CALÇADO VEGAN, LDA.	PT	PT	COMBINED	COMPANY	BUSINESS	25
000526106	2014	NOOCITY	CIDADE COM PERFIL - ECOLOGIA URBANA, LDA	PT	PT	COMBINED	COMPANY	STARTUP	21,31,44
015880347	2016	NOOCITY	CIDADE COM PERFIL - ECOLOGIA URBANA, LDA	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	STARTUP	21,31,44
000460355	2010	RESPIGA	ANA CLÁUDIA DO COUTO FERREIRA	PT	PT	WORD	ENTREPRENEUR	STARTUP	6,2

017099797	2017	S SOJA DE PORTUGAL SINCE 1943	SOJA DE PORTUGAL	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	BUSINESS	36
000039698	2016	SOJA DE PORTUGAL DESDE 1943	SOJA DE PORTUGAL	PT	PT	COMBINED	COMPANY	BUSINESS	UNDEFINED
000008886	2006	HERDADE VALE DA ROSA	ANTONIO JOSE RAMOS SILVESTRE FERREIRA	PT	PT	COMBINED	ENTREPRENEUR	BUSINESS	UNDEFINED
000404249	2006	HERDADE VALE DA ROSA	ANTONIO JOSE RAMOS SILVESTRE FERREIRA	PT	PT	COMBINED	ENTREPRENEUR	BUSINESS	16,31
000511780	2013	SKIN4YOU	VILARTEX - EMPRESA DE MALHAS VILARINHO, LDA.	PT	PT	COMBINED	COMPANY	BUSINESS	24,25
000384071	2004	4 SKIN	VILARTEX - EMPRESA DE MALHAS VILARINHO, LDA.	PT	PT	COMBINED	COMPANY	BUSINESS	24,25
000540982	2015	SIMPLES ENERGIA	PH ENERGIA, UNIPESSOAL LDA	PT	PT	COMBINED	COMPANY	BUSINESS	39
010280238	2011	LOGOPLASTE INNOVATION LAB	LOGOPLASTE INNOVATION LAB, LDA	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	BUSINESS	42
000535474	2014	WISECROP	WISE CONNECT, UNIPESSOAL, LDA	PT	PT	COMBINED	COMPANY	STARTUP	9,42

1126992	2012	CLOOGY	VIRTUAL POWER SOLUTIONS, S.A.	WO	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,FI,D K,IE,CZ,AT,C Y,US,SE,SI,SK, IT,MT,PT,PL,E M,GR,ES,NL,E G,EE,CN	WORD	COMPANY	BUSINESS	9,38,42
UK000031647 29	2016	KIPLO	VIRTUAL POWER SOLUTIONS, S.A.	GB	GB	FIGURATIVE	COMPANY	BUSINESS	9,42
000565187	2016	KIPLO	VIRTUAL POWER SOLUTIONS, S.A.	PT	PT	COMBINED	COMPANY	BUSINESS	9,42
006110266	2007	SMART ENERGY	VIRTUAL POWER SOLUTIONS, S.A.	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,DK, FI,IE,CZ,AT,C Y,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	WORD	COMPANY	BUSINESS	41,45
000587244	2017	HOTEL UP	VIRTUAL POWER SOLUTIONS, S.A.	PT	PT	COMBINED	COMPANY	BUSINESS	35,42
000484052	2011	S:WALL	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,35,37 ,43
000431228	2008	TREEHOUSE	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,35,37
000484051	2011	S:VINYL	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,35,37 ,43
000456028	2009	MEGAPAN	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,35,37
000395423	2005	S:OLID	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19
000477237	2011	TREEHOUSE	JULAR MADEIRAS	PT	PT	WORD	COMPANY	BUSINESS	43
000477235	2011	TREEHOTEL	JULAR MADEIRAS	PT	PT	WORD	COMPANY	BUSINESS	43

006821921	2008	TREEHOUSE HABITE O SEU SONHO	JULAR MADEIRAS	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,FI,D K,IE,CZ,AT,C Y,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	BUSINESS	19,35,37
000395422	2005	S:TRAT	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19
000027881	2012	AUZZ	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	UNDEF INED
000395425	2005	S:LIM	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19
000395424	2005	S:WOOD	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19
1095830	2011	TREEHOUSE HABITE O SEU SONHO	JULAR MADEIRAS	WO	JP	FIGURATIVE	COMPANY	BUSINESS	19,35,37
000395426	2005	S: LIMLEAF	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19
000406721	2006	S:DECK	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19
000576961	2017	THOUSE	JULAR MADEIRAS	PT	PT	WORD	COMPANY	BUSINESS	19,35,37
000386899	2004	TERMOPAN	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19
000576976	2017	TRUEHOUSE	JULAR MADEIRAS	PT	PT	WORD	COMPANY	BUSINESS	35,37
000019113	2009	ONWOOD TAKE AND DO IT	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	UNDEF INED
000522946	2013	SWLODGE	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,35,37
000514932	2013	JULAR MADEIRAS	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,37
000491173	2011	MINT HPL	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19

000456403	2009	ONWOOD TAKE AND DO IT	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,35,37
000024296	2011	JULAR MADEIRAS	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	UNDEFINED
000506857	2012	AUZZ	JULAR MADEIRAS	PT	PT	COMBINED	COMPANY	BUSINESS	19,35,37
1155445	2013	OIL2WAX	OIL2WAX INNOVATIVE MATERIALS	WO	JP,US,RU,KR, AU,CN	FIGURATIVE	COMPANY	STARTUP	40
1620966-00	2013	UNDEFINED	OIL2WAX INNOVATIVE MATERIALS	CA	CA	FIGURATIVE	COMPANY	STARTUP	4,40,41
1614572-00	2013	UNDEFINED	OIL2WAX INNOVATIVE MATERIALS	CA	CA	FIGURATIVE	COMPANY	STARTUP	40,41,42
1161495	2013	THE GREATEST CANDLE IN THE WORLD	OIL2WAX INNOVATIVE MATERIALS	WO	JP,US,RU,KR, AU,CN	FIGURATIVE	COMPANY	STARTUP	4
011081023	2012	O2W	OIL2WAX INNOVATIVE MATERIALS	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,FI,DK,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	STARTUP	40,41,42
011292265	2012	THE GREATEST CANDLE IN THE WORLD	OIL2WAX INNOVATIVE MATERIALS	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,FI,DK,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	STARTUP	4,40,41

011126571	2012	OIL2WAX	OIL2WAX INNOVATIVE MATERIALS	EM	LV,LU,LT,GB, HR,RO,HU,BG, FR,BE,DE,FI,DK,IE,CZ,AT,CY,SE,SI,SK,IT, MT,PL,PT,EM, GR,ES,NL,EE	FIGURATIVE	COMPANY	STARTUP	40,41,42
840483287	2013	THE GREATEST CANDLE IN THE WORLD	OIL2WAX INNOVATIVE MATERIALS	BR	BR	COMBINED	COMPANY	STARTUP	4
840421400	2013	OIL2WAX	OIL2WAX INNOVATIVE MATERIALS	BR	BR	COMBINED	COMPANY	STARTUP	40
905079248	2012	NATUREPURA	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	COMBINED	COMPANY	BUSINESS	25
905079493	2012	NATUREPURA	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	COMBINED	COMPANY	BUSINESS	28
905079086	2012	NATUREPURA	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	COMBINED	COMPANY	BUSINESS	24
902112120	2009	NATURAPURA THE PURELY ECOLOGICAL BRAND	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	COMBINED	COMPANY	BUSINESS	25

902112171	2009	NATURAPURA THE PURELY ECOLOGICAL BRAND	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	COMBINED	COMPANY	BUSINESS	28
902112015	2009	NATURAPURA THE PURELY ECOLOGICAL BRAND	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	COMBINED	COMPANY	BUSINESS	24
03008/2004	2004	NATURA PURA THE PURELY ECOLOGICAL BRAND	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	CH	CH	COMBINED	COMPANY	BUSINESS	24,25,28
78275488	2003	NATURA PURA	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	US	US	WORD	COMPANY	BUSINESS	24,25
825545978	2003	NATURA PURA	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	WORD	COMPANY	BUSINESS	25
825545986	2003	NATURA PURA	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	BR	BR	WORD	COMPANY	BUSINESS	24

1370612-00	2007	NATURAPURA	NATURAPURA IBÉRICA - PRODUÇÃO E COMÉRCIO DE PRODUTOS NATURAIS, S.A.	CA	CA	WORD	COMPANY	BUSINESS	25, 28
000413296	2007	LIPOR SERVIÇO INTERMUNICIPALIZ ADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	LIPOR - SERVIÇO INTERMUNICIPALIZA DO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	COMBINED	COMPANY	BUSINESS	35, 41
000010075	2007	LIPOR SERVIÇO INTERMUNICIPALIZ ADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	LIPOR - SERVIÇO INTERMUNICIPALIZA DO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	COMBINED	COMPANY	BUSINESS	UNDEF INED
000392872	2005	DAKELE	LIPOR - SERVIÇO INTERMUNICIPALIZA DO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	WORD	COMPANY	BUSINESS	1
000551510	2015	ECOSHOP LIPOR	LIPOR - SERVIÇO INTERMUNICIPALIZA DO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	COMBINED	COMPANY	BUSINESS	9,16,35, 39,41
000014699	2008	CENTRO AMBIENTAL DE LAÚNDOS LÉGUA DA PÓVOA	LIPOR - SERVIÇO INTERMUNICIPALIZA DO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	COMBINED	COMPANY	BUSINESS	UNDEF INED
000392873	2005	FERTITEK	LIPOR - SERVIÇO INTERMUNICIPALIZA DO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	WORD	COMPANY	BUSINESS	1

000440732	2008	CENTRO AMBIENTAL DE LAÚNDOS LÉGUA DA PÓVOA	LIPOR - SERVIÇO INTERMUNICIPALIZADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	COMBINED	COMPANY	BUSINESS	35, 40, 41
000399111	2006	LIPOR	LIPOR - SERVIÇO INTERMUNICIPALIZADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	WORD	COMPANY	BUSINESS	35
000394946	2005	HORTA À PORTA	LIPOR - SERVIÇO INTERMUNICIPALIZADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	WORD	COMPANY	BUSINESS	41,44
000394945	2005	HORTA DA FORMIGA	LIPOR - SERVIÇO INTERMUNICIPALIZADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	WORD	COMPANY	BUSINESS	41
000392871	2005	NUTRIMAIS	LIPOR - SERVIÇO INTERMUNICIPALIZADO DE GESTÃO DE RESÍDUOS DO GRANDE PORTO	PT	PT	WORD	COMPANY	BUSINESS	1

Appendix 8 - Delphi invitation sent to CE "experts"

Dear Sirs,

I am a Global Studies PHD student at the New University of Lisbon (Portugal). My current research focuses on innovation and circular economy. I am especially interested in the role of eco-innovation in the implementation and/or development of a circular economy.

As these are complex issues that have not been thoroughly researched, lacking documented information, I am preparing a Delphi study, which is the reason why I am contacting you.

A Delphi study is a method used in exploratory research to gather opinions from experts (academia, scientific community, and other stakeholders) about novel ideas or complex problems, by conducting several consecutive questionnaires with controlled feedback.

The exercise will comprise, at most, three rounds of consecutive surveys of 15 minutes each. After each round, a summary of the results gathered will be made available following a new enquiry.

The practical nature of this exercise can prove interesting for your organisation, as it will help ascertaining strong tendencies regarding the global implementation of circular economy; identify possible future avenues of development; get in contact with the combined experience of several experts on this field; as well as recognise objective tools for boosting business within that paradigm.

With this in mind, I would like to ascertain your availability to participate in the Delphi study as a circular aware enterprise.

Your participation would be highly appreciated and I would like to assure you that the individual results and participation will be anonymous. Naturally, the overall results of the study will be available on request.

I am, of course, at your disposal if any doubts arise and counting on hearing from you soon.

Sincerely,

Ana de Jesus

Appendix 9 - Reflections on the use of the Delphi: Methodological difficulties and links between rounds

Some additional considerations regarding the Delphi method used in this research are further discussed in this section, namely regarding participation issues and rounds' construction/definition. Participation and engagement in the Delphi Rounds was sought throughout the exercise as to improve response rates, not only by choosing experts really interested in the topic, trying to limit fatigue, and stressing experts contributions in the development of following rounds (Geist, 2010; Keeney, 2010). Also, in order to work around experts' agenda, the Delphi stopped from August to September and in December (to accommodate summer and winter breaks) 2016. Each survey was also available for a significant period of time (approximately 1 month) with a minimum of 3 reminders sent to respondents. Response rate of 58% in the last Round (17 of the overall 29 experts) is within the anticipated acceptance rate for this kinds of studies (Gordon, 1994).

Regarding the structuration of each of the three Delphi Rounds this was a cumulative exercise with one round adding to the preceding one. The main purpose of the first round was to recognise general topics on how experts, enterprises and other institutions understand and foresee the development of a CE, and its main topics. This was a more conceptual exercise as the following rounds were more policy-oriented.

The data analysis from the first round highlighted a number of questions which led to a partial reconfiguration and redesign of the following surveys (Appendix 11). The second survey was divided therefore in four sections concerning: 1) CE functional definition; CE inherent barriers and drivers, and factors essential to further develop CE implementation; 2) focus on socio-cultural issues and consumer innovation (co-creation as a way to overcome CE barriers; 3) identification of organisational strategies 4) identification of a policy roadmap. In this second round the participants were asked to review items identified by the first round of the Delphi and asked to rank-order items or use a Likert-type rating scale to establish priorities among items. They were also invited to comment on their rationale for the rating and add additional items.

The final (third) round intended to clarify the information already gather and better understand its importance focused on policy-orientations. As in the second round, before the last survey, a summary of results (including statistical feedback of their own answers) was provided. This feedback aimed to make respondents aware of the group's range of opinions. The third and last survey was inspired by the second round but did not re-examine the whole set of questions of stage two (Appendix 11). Rather, it reviewed items that either raised doubts and where agreement did not occur, asking experts to re-rate and establish priorities in previously identified findings. The focus was to make clarifications regarding the information already gathered and better understand its importance namely in policy roadmaps and organisational strategies. As Barnes and Mattsson (2016) we combined Likert and ranking-type Delphi questions in order to benefit from the advantages of both. After the second and third rounds there is nevertheless only a small increase in the degree of consensus, as it happens in other similar studies (Hsu and Sandford, 2007). This is nonetheless not overly problematic for two reasons. First, our key objective was not to reach consensus, but to get a picture of differing viewpoints and key arguments, recognising main trends and understanding possible evolution of the CE approach, as well as to gather information on innovation policy implications in that context. Secondly, as Keeney (2010) stress, consensus in a Delphi study is not equivalent to the identification of the "correct answer". Limited, or lack of, consensus indicate a conceptual restlessness in the field of CE that polarise specialist's opinions. This *per se* is a result.

Appendix 10 - 1st Round Survey

Question	Type	Justification
Part 1 - CE toward sustainability		
A. In the sustainability debate what do you think is the importance of CE ?	Open question	Difficulty in settle a definition of CE (Kirchherr et al., 2017). Many different definitions and meanings, from several actors, can be found (EIO, 2016; EMF, 2012, p. 212; Geissdoerfer et al., 2017; Murray et al., 2017, p. 201; Standing Committee of the National People's Congress - China, 2009)
B. Which do you think are the prospects of development of a CE for the next 20 years	Open question	Pursuit of a CE is considered central within the EU agenda, with the Commission's Circular Economy Action Plan stressing the EU's commitment and support for CE (EC, 2017a).
C. Which are the most important drivers that you identify in the development and implementation of CE?	Semi open question	Drivers of a transformative reorganisation are of policy interest (de Jesus et al., 2018)
D. Which are the most important barriers that you identify in the development and implementation of CE?	Semi open question	Barriers to a transformative reorganisation are of policy interest (de Jesus et al., 2018)
E. Why is CE not yet further developed?	Open question	Even with global trends (linked with resource volatility; stringent regulatory frameworks; etc.) heightening the importance of a more CE the approach is hampered by several factors (de Jesus et al., 2018). Despite the literature addressing innovation governance and policy, a knowledge gap is still apparent on assessing convergence to circularity (Hillman et al., 2011; Lieder and Rashid, 2016). Noteworthy as well is the lack of a comprehensive discussion concerning CE empirical indicators (Elia et al., 2017; Hezri and Dovers, 2006)
F. How do you think CE implementation could be boosted?	Open question	Systemic EI and innovation policies implications: "the success of circular economy models will depend on adopting a systemic approach to eco-innovation that encompasses value and supply chains in their entirety and engages all actors involved in such chains." (EC, 2015b, p. 73)
Part 2 - Innovation Towards CE		
G. Innovation is important in the transition to a CE? And innovation with the consumer (co-creation) do you think it is: (1.Not at all important; 2.Not very important; 3. Moderately important; 4. Very Important; 5. Extremely Important)	Semi open/ Likert question	Discussing CE and its close connection with innovation. Several authors emphases on CE as a driver for EI, a "leading principle for eco-innovation, aiming at 'zero waste' society and economy" (Mirabella et al., 2014, p. 29). Others focus the pivotal role of EI : "the capacity of eco-innovations to provide new business opportunities and contribute to a transformation towards a sustainable society" (Carrillo-Hermosilla et al., 2010, p. 102). The importance of consumers as "part of the supply chain" and as "innovative agents" has not yet been properly addressed in the development of a CE.
H. What do you think is the value of innovation with end users in the implementation and development of circularity?	Open question	Questions related with other kinds of innovations that are less discussed in events as the Rio+20 (Ely et al., 2013).
I. How to engage civil society in circularity?	Open question	Consumer awareness to CE and the development of new business models is still considered lacking (Albu, 2011).

Appendix 11 - 2nd and 3rd Round – Questions

N'	Question	Type of question Round 2	Round 3
	Part 1 - CE toward sustainability		
1	Could CE be defined as a transformational re-organised economic model that contributes to economic development by coordinating production systems and consumption habits into a production-usage closed circuit?	Likert	Likert
	1.1 Why	Open	Open
2	What do you think is the CE general value in the sustainability debate?	Likert	Closed in Round 2
	2.1 As a more helpful and tangible concept than other definitions, namely “green economy”, ’cradle-to-cradle’ or ‘green growth’		
	2.2 As a multidimensional concept towards a paradigm change		
	2.3 As a “business friendly” concept in the sustainability debate		
	2.4 As a “buzz word”, a new expression for something well known, not a new concept		
	2.5 As an approach somewhat difficult to define and distinguish from “sustainability”		
	2.6 As the only economic viable strategy considering nowadays’ resource limitations		
3	Which drivers do you think are more important?	Ranking	Ranking
	3.1 Economic/ Financial/ Market factors		
	3.2 Institutional/Regulatory factors		
	3.3 Socio/Cultural factors		
	3.4 Technical factors		
4	Which barriers do you think are more important?	Ranking	Ranking
	4.1 Economic/ Financial/ Market factors		
	4.2 Institutional/Regulatory factors		
	4.3 Socio/Cultural factors		
	4.4 Technical factors		
5	What types of eco-innovations are more important in making the old redundant and give rise to a circular model?	Likert	Ranking
	5.1 Good or service eco-innovation – new product or service, tangible or intangible		
	5.2 Process eco-innovation – novel or meaningfully improved production or delivery method		
	5.3 Marketing eco-innovation – significant changes in product design or packaging, product placement, product promotion or pricing		
	5.4 Organisational eco-innovation – novel organisational method in business, workplace organisation		
	5.5 Systemic eco-innovation – approach to eco-innovation that encompasses all value chain and engages all actors involved		
6	Which “mechanisms” do you consider as more important?	Likert	Closed in Round 2
	6.1 Technological – focus on technological innovation		
	6.2 Non-technological – focus on non-technological innovation		

Part 2 – Civil Society - Testing consumer innovation			
7	Do you agree that innovation with end users is important in the implementation and development of circularity	Likert	Closed in Round 2
8	And in 2030?	Likert	Closed in Round 2
9	Do you think innovation with customer engagement and collaboration: 9.1 Co-creation do not benefit CE development as what consumers say are not what they want, need or do 9.2 Co-creation might "open the doors to more people making more stuff, and not developing the infrastructure to manage it themselves" 9.3 Using technology to tackle CE problems "seems a better idea than any form of co-creation" 9.4 Co-creation can be used to identify opportunities or "business blind spots" 9.5 Co-creation, co-developed with the end-user, is important to avoid market failure	Likert	Closed in Round 2
10	How can Civil Society better encourage circularity? 10.1 Promote "circular" consumer communities to raise awareness and inform society 10.2 Use social media and the web to provide consumer input raise awareness and inform society 10.3 Participate in co-creation challenges/ innovation contests 10.4 Promote the participation in the development of "circular" goods and services	Started only in Round 3	Ranking
Part 3 – Organisational strategies			
11	What strategies could be developed by companies? 11.1 Develop network of cooperation with other enterprises (suppliers and clients) to ensure circularity 11.2 Innovation with consumers – Promote co-creation with customers (e.g. innovation contests; product-related discussion forums and communities of creation; open source software; etc.) 11.3 Invest in new "circular" business models 11.4 Promote contacts and partnerships with universities an R&D research centres 11.5 Promote internal communication and cooperation between departments namely innovation, design, engineering	Likert	Ranking
Part 4 – Policy roadmap			
12	Which innovation policy goals better encourage circularity? 12.1 Dedicated tax policy 12.2 Develop financial tools to support circular economy eco-innovations 12.3 Encourage industry sectors to deliver specific transition plans 12.4 Encourage "circular" procurement 12.5 Enhance demand (support and encourage actors' awareness and increase social participation) 12.6 Private and public investment in R&D and base science to support circularity 12.7 Promote science education and training 12.8 Providing an institutional regulatory framework 12.9 Strengthen policies on waste avoidance to encourage innovation – new product designs, and use of recycled or reused materials	Likert	Ranking

Note: At the end of all questions a "Comments" section was included to enable experts to post additional information regarding their choices.

Appendix 12 - 2nd and 3rd Round – Summary of findings

Nº	% Likert Scale 4-5		Standard deviation		Median		Mean		% of respondents placing each item in the top half of their list		Kendell's W		IIQ (Q3-Q1) Consensus < = 1	
	R 2	R 3	R 2	R 3	R2	R 3	R 2	R 3	R 2	R 3	R 2	R 3	R 2	R 3
Part 1 - CE toward sustainability														
1	52%	53%	1.03	1.12	4	4	3.19	3.47					1.00	1.00
1.1	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
2														
2.1	57%	Closed in Round 2	1.25	Closed in Round 2	4	Closed in Round 2	3.43	Closed in Round 2					1.00	Closed in Round 2
2.2	81%		0.92		4		3.95						0.00	
2.3	71%		0.89		4		3.76						1.00	
2.4	**38%**		1.14		3		3.10						**2.00**	
2.5	**24%**		0.83		3		2.76						1.00	
2.6	**33%**		1.14		3		3.00						**2.00**	
3														
3.1			0.65	1.11	1	1	1.38	1.65	90%	77%	0.37	**0.33**	1.00	1.00
3.2			0.97	0.90	3	2	2.90	2.24	33%	35%			**2.00**	1.00
3.3			1.05	0.92	3	3	2.57	2.71	48%	71%			1.00	1.00
3.4			0.83	0.80	3	4	3.14	3.41	29%	18%			**2.00**	1.00
4														
4.1			0.79	0.80	1	1	1.52	1.53	81%	82%	0.45	0.52	1.00	1.00
4.2			0.79	0.97	3	3	2.33	2.24	48%	41%			1.00	1.00
4.3			0.99	0.72	2	2	2.52	2.47	57%	65%			1.00	1.00
4.4			0.72	0.66	4	4	3.62	3.76	14%	12%			0.00	0.00
5														
5.1	77%		0.68	0.86	4	2	3.81	2.35		71%		0.66	0.00	1.00
5.2	57%		0.66	1.01	4	3	3.67	3.18		18%			1.00	1.00
5.3	67%		0.98	0.79	4	5	3.52	4.65		6%			1.00	0.00
5.4	62%		0.98	0.80	4	4	3.57	3.59		12%			1.00	1.00
5.5	100%		0.51	0.75	5	1	4.57	1.24		94%			1.00	0.00
6														
6.1	71%		0.54	Closed in Round 2		Closed in Round 2	3.76	Closed in Round 2					1.00	Closed in Round 2
6.2	76%		0.80				3.95						0.00	
Part 2 - Civil Society - Testing consumer innovation														
7	57%	Closed in Round 2	0.77	Closed in Round 2	4	Closed in Round 2	3.76	Closed in Round 2					1.00	Closed in Round 2
8	76%	Closed in Round 2	0.74	Closed in Round 2	4	Closed in Round 2	4.05	Closed In Round 2					1.00	Closed in Round 2
9														
9.1	**24%**	Closed in Round 2	1.04	Closed in Round 2	3	Closed in Round 2	1.04	Closed in Round 2					1.00	Closed in Round 2
9.2	57%		0.81		4		0.81						1.00	
9.3	**38%**		0.83		3		0.83						1.00	
9.4	71%		0.81		4		0.81						1.00	
9.5	52%		0.87		4		0.87						1.00	
10														
10.1				0.33		1		1.12		100%		0.59		0.00
10.2				1.01		2		2.47		65%				1.00
10.3				0.66		3		3.06		18%				0.00
10.4				0.79		4		3.35		18%				1.00

Part 3 - Organisational strategies														
11														
11.1	91%		0.64	0.95	4	2	4.29	2.18		94%		0.70	1.00	0.00
11.2	76%		1.07	0.56	4	5	3.95	4.76		6%			1.00	0.00
11.3	100%		0.51	0.87	5	1	4.52	1.41		94%			1.00	0.00
11.4	81%		0.63	0.88	4	4	4.00	3.82		18%			0.00	0.00
11.5	90%		0.77	0.64	4	3	4.24	2.82		88%			1.00	1.00
Part 4 - Policy roadmap														
12														
12.1	62%		1.16	**2.24**	4	8	3.57	7.18		18%		0.50	1.00	1.00
12.2	57%		0.98	**1.82**	4	7	3.57	5.94		35%			1.00	**2.00**
12.3	57%		1.12	**1.93**	4	9	3.38	7.71		12%			1.00	**2.00**
12.4	67%		0.84	**2.67**	4	1	4.00	2.88		82%			**2.00**	**3.00**
12.5	81%		0.59	1.58	4	3	3.95	3.12		94%			0.00	1.00
12.6	76%		0.77	**1.71**	4	4	3.90	4.24		77%			0.00	**2.00**
12.7	71%		0.75	1.59	4	6	3.81	5.82		41%			1.00	**3.00**
12.8	67%		1.01	**1.95**	4	6	3.71	5.76		41%			1.00	**2.00**
12.9	81%		0.89	1.06	4	2	4.00	2.35		100%			1.00	1.00

Note: Bold when consensus was not reached

MAIN CONTRIBUTIONS OF THE PhD CANDIDATE

Book chapters

- De Jesus, A. e Mendonça, S. "As implicações económicas da Conferência de Paris: Oportunidades para os sectores produtivos" in José Silva (Eds.) *COP 21 Desafios para Portugal depois da conferência de Paris*. Editora da Universidade de Lisboa. (forthcoming https://ciencia.iscte-iul.pt/publications/as-implicacoes-economicas-da-conferencia-de--parisoportunidades-para-os-sectores-produtivos/33974).

Conference participation

- "The grand green challenge: Assessing progress in eco-innovation through Y02 patents" in the Conference "Governance of a Complex World" (gcw2015) in Nice (France) - July (1-3) 2015

  The main theme of this conference was "*knowledge, innovation and development issues in the pursuit of a smart, sustainable and inclusive growth in Europe"*. This event gathered several scientists of the fields of economics and social sciences, but also of mathematics, physics, computer sciences, environment and life sciences.

  https://gcw2015.sciencesconf.org/conference/gcw2015/pages/GCW_2015_STRUCTURE_18_06_15.pdf

Published Papers

Related with the Doctoral Program on Global Studies (Peer reviewed)

- De Jesus, A. e Oliveira e Silva, B. (2017) "Ambiente, "economia verde" e Direitos Humanos. Uma visão integrada." in Análise Social, 223, lii (2.o), pp. 306-327. Available at: http://analisesocial.ics.ul.pt/documentos/AS_223_art03.pdf

- De Jesus, A. e Oliveira e Silva, B. (2015) "Ambiente e saúde global" in Fórum Sociológico, Número 26, pp. 65-72. Available at: http://journals.openedition.org/sociologico/1216

Related with the Dissertation Scope (Peer reviewed)

- de Jesus, A.; Mendonça, S. (2018) "Lost in transition? Drivers and barriers in the eco-innovation road to the Circular Economy" in "Ecological Economics" 145 pp. 75-89. Available at: http://www.sciencedirect.com/science/article/pii/S0921800916316597

- de Jesus, A.; Santos, Rui Ferreira dos; Antunes, Paula; Mendonça, S (2018) "Eco-Innovation in the transition to a circular economy: An analytical literature review" in Journal of Cleaner Production. Available at: http://www.sciencedirect.com/science/article/pii/S0959652617327853

Related with the Dissertation Scope

- de Jesus, A.; Santos, Rui Ferreira dos; Antunes, Paula (2016), Economia Circular - um quadro estratégico, regenerativo e mobilizador. Revista Industria e Ambiente, nº98, pp.10-12. Available at: http://www.industriaeambiente.pt/noticias/revista-n98-maio-junho-2016/

Submitted and Under Review

- de Jesus, A.; Santos, Rui Ferreira dos; Antunes, Paula; Mendonça, S. "Understanding the priorities in the eco-innovation pathway to a Circular Economy transition: A Delphi study" submitted to Ecological Economics

Summer School course organisation

- Participated in the organization, teaching and promotion of the course "Ameaça ou Oportunidade? Limites ecológicos à segurança global" (Threat or Opportunity? Ecological Limits to Global Security) in FCSH 2016 Summer School (25-27 July, FCSH NOVA)

  https://www.dcea.fct.unl.pt/sites/www.dcea.fct.unl.pt/files/imagens/noticias/2016/06/flyer_EV%202016%20%281%29.pdf

  https://www.dcea.fct.unl.pt/noticias/2016/06/escola-de-verao-2016-fcsh-nova

Other activities

- Collaborated with the UN, in the Global Sustainable Development Report 2015, (2014)

- Participated in the design, organization and operationalization of the Eco.nomia platform, dedicated to the Circular Economy, promoted by the Portuguese Ministry of the Environment (between 2016 and 2017).

- Reviewer in several international journals/publications such as: The Springer Handbook of Science and Technology Indicators; Journal of Cleaner Production (2017).

- NOVA Doctoral School courses attended:
    - UNL Winter School: Research Design Seminar – February (17-20) 2014
    - UNL Winter School: Social Network Analysis – March (9-12) 2015
    - UNL Winter School: The Essentials of Quantitative Research. Data Analysis in R. – March (09-12) 2015
    - UNL Doctoral School: Intellectual Property Rights - March (19/26) 2015
    - April (7 – 9) 2016 - Social Media for scientists
    - June (7 – 8) 2016 - Design Thinking Course

- Frequency of additional training courses:
    - Patstat online: an overview. Patstat Webinar - September (30) 2015
    - Scopus Advanced research tips and tricks – January (27)
    - Curso Nvivo11 – July (9) 2016
    - The Age of Sustainable Development Course. Coursera – January to April 2014

- Frequency of conferences and seminars:
    - Ecological modernisation theory and practice. Arthur Mol from Wageningen University. CIES – November (21) 2014
    - Being the new change. CULTURGEST- March (11) 2015

- Consumo Sustentável - Uma Atitude Verde. I Conferência Green Project Awards 2015. Fundação Calouste Gulbenkian Foundation, Green Project Awards, Aped, Deco, ICS and Observa - May (5) 2015
- Crescimento Verde e Oceano – fim de vida dos produtos. Green Project Awards and Veolia – June (5) 2015
- Disruptive innovation festival (DIF). Ellen MacArthur Foundation - October to November 2014
- Ponto Verde Open Innovation: «Acelerar rumo à Economia Circular» - February (2) 2016.
- "Financiamento da Economia Circular" Ministério do Ambiente – April (11) 2016
- "Cop 21 desafios para Portugal" Universidade de Lisboa – April (22) 2016
- H&M "Evento 100% circular" – April (18) 2016
- Conference "Fechar o Ciclo - Combater o Desperdício" II Conferência GPA - May (18) 2016
- "Lançamento do portal eco.nomia dedicado à Economia Circular" Ministério do Ambiente - October (21) 2016