H2020 Innovation Action - This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 760792

fenix

WP1 – NEW BUSINESS MODELS IDENTIFICATION

Task 1.1 – Business Models Identification

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Deliverable No.:	1.1
Work Package No.:	WP1
Date:	18.04.2018
Project No.:	760792
Classification:	Public
File name:	FENIX_D1.1 report
Number of pages:	47

Status of deliverable

Action	By	Date (dd.mm.yyyy)
Submitted (author(s))	Paolo Rosa, Claudio Sassanelli, Sergio Terzi	24.04.2018
Responsible (WP Leader)	Sergio Terzi	
Approved by Peer reviewer	Ionela Birloaga (UNIVAQ), Dimitris Ntalaperas (SINGULAR)	18.04.2018

Revision History

Date (dd.mm.yyyy)	Revision version	Author	Comments
09.03.2018	v0	Paolo Rosa, Sergio Terzi	draft version
19.03.2018	v1	Paolo Rosa, Sergio Terzi	draft version
21.03.2018	v2	Paolo Rosa, Sergio Terzi	draft version
22.03.2018	v3	Paolo Rosa, Sergio Terzi	draft version
26.03.2018	v4	Paolo Rosa, Sergio Terzi	draft version
28.03.2018	v5	Paolo Rosa, Claudio Sassanelli, Sergio Terzi	draft version
30.03.2018	v6	Paolo Rosa, Claudio Sassanelli, Sergio Terzi	draft version
04.04.2018	v7	Paolo Rosa, Claudio Sassanelli, Sergio Terzi	draft version
14.04.2018	v8	Paolo Rosa, Claudio Sassanelli, Sergio Terzi	draft version
18.04.2018	v9	Paolo Rosa, Claudio Sassanelli, Sergio Terzi	final version

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ABSTRACT

The main aim of the FENIX project is the development of new business models and industrial strategies for three novel supply chains in order to enable value-added product-services. Through a set of success stories coming from the application of circular economy principles in different industrial sectors, FENIX wants to demonstrate in practice the real benefits coming from its adoption. In addition, Key Enabling Technologies (KETs) will be integrated within the selected processes to improve the efficient recovery of secondary resources. Deliverable 1.1 focuses on the identification of the most suitable Circular Business Models (CBMs) to be implemented within the FENIX project. This identification activity followed a multi-perspective evaluation process. From one side, a state of the art analysis of existing CBMs has been executed and the most common classification framework exploited to define the archetypes of CBMs to be assessed by the FENIX partners. In parallel, a set of interviews with all the FENIX partners have been carried out, trying to identify the most important benefits expected from the adoption of CBMs. At the end, the integration of these two views allowed the definition of the most suitable CBMs to be adopted in FENIX. The identified CBMs are: product-oriented, use-oriented and result-oriented Product-Service Systems (PSSs). Subsequently, these CBMs will be assessed in terms of their circularity performance in Deliverable 1.2 (Business models circularity assessment).

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Abbreviations and Acronyms:	
AM	Additive Manufacturing
BM	Business Model
BOL	Beginning Of Life
CBM	Circular Business Model
CE	Circular Economy
CEBM	Circular Economy Business Model
EOL	End Of Life
GBM	Green Business Model
ICT	Information and Communication Technology
KET	Key Enabling Technology
MOL	Middle Of Life
PSS	Product-Service System
SBM	Sustainable Business Model
SME	Small and Medium Enterprise

1. INTRODUCTION

Deliverable 1.1 identifies a set of Circular Business Models (CBMs) to be adopted within the FENIX project. To do that, a multi-perspective procedure has been established. First of all, a state of the art analysis defined what are the most common types of CBMs and how they can be classified (e.g. what are the CBMs archetypes). Secondly, a set of dedicated interviews with the FENIX industrial partners identified what are the most important benefits expected from the adoption of circular practices within companies. Together, the integration of both the scientific and the industrial perspective was used to select the most suitable CBMs to consider within the FENIX project. Then, the intent of Deliverable 1.2 will be the circularity assessment of those CBMs. Deliverable 1.1 is structured as follows. Section 2 is dedicated to the literature assessment about CBMs. Section 3 follows the same logic, but with the final aim of identifying the industrial benefits expected from the adoption of Circular Economy (CE) practices. Section 4 puts together results coming from the previous two sections for the final identification of the most suitable CBMs to be adopted in FENIX. Section 5 gives some concluding remarks and future activities.

2. STATE OF THE ART OF CIRCULAR BUSINESS MODELS (CBMs)

The intent of this section is the analysis of the state of the art about circular business models. Starting from a generic view of circular economy, a dedicated focus will be given to its effect on traditional business models and how these effects influence the transition towards circular business models. A second element of analysis will be related with the existing methods for the classification of circular business models and the definition of the so called "archetypes". Given all of these information, a final selection of the FENIX CBMs will be described.

2.1. Current state of the art on CBMs

Circular Business Models (CBMs) can be considered like the translation of circular economy principles within the company's boundaries. Depending on the experts, CBMs (also named Circular Economy Business Models – CEBMs) can be classified under the wider umbrella of either Green Business Models (GBMs) and/or Sustainable Business Models (SBMs). Trying to gather some interesting details on current aspects related with CBMs, a systematic literature review on scientific articles published from 2000 up to the first quarter of 2018 and provided by the most popular academic search engines (e.g. Google Scholar, SAGE, Science Direct, Springer, Taylor&Francis Online and Wiley Online Libraries) has been carried through. Current findings say that the attractiveness of CBMs increased especially during the last years, when international environmental protection organizations started in defining and promoting even more restrictive regulations. **Figure 1** displays results of the search process, in terms of number of articles per year, and publications trend. The total amount of articles (283) reveals the relevant attention devoted to this topic (from 2000 up to 2018-first quarter) by the experts, especially in 2016 and 2017. A total of 158 articles were published in scientific journals with impact factor, 26 in scientific journals without impact factor, 64 in proceedings of scientific conferences, 24 scientific reports, 8 book chapters and 2 industrial reports.

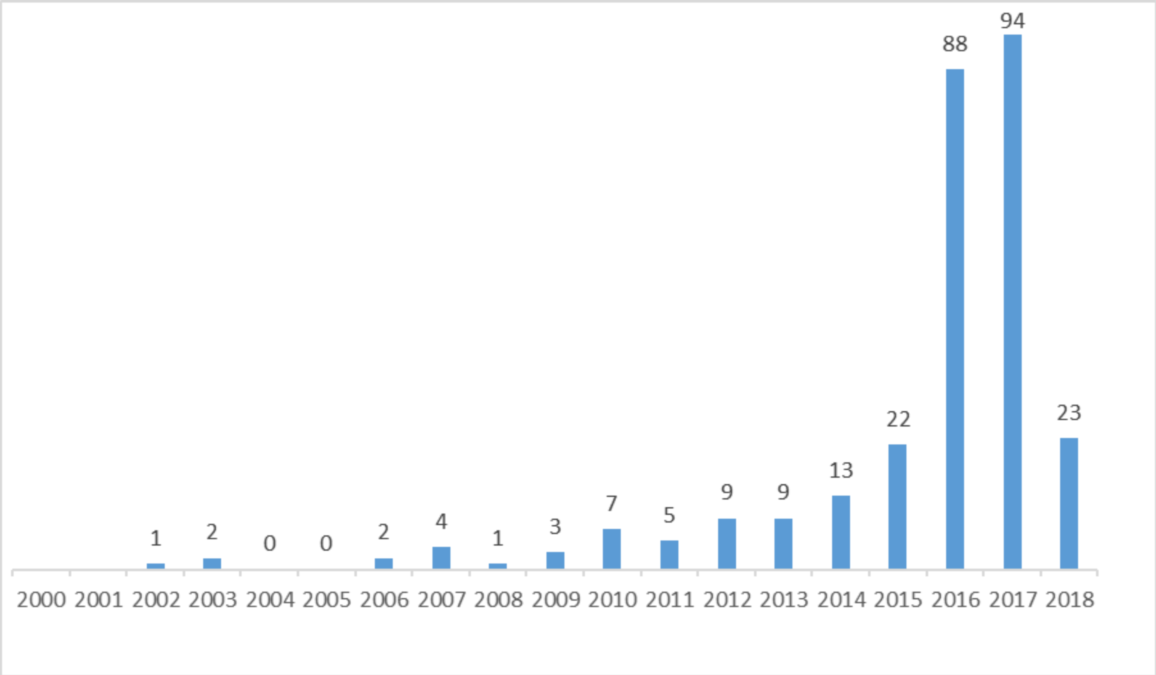

Figure 1: Historical series of published articles

In general terms, the literature usually assesses CBMs following two different strategies: 1) a theoretical view and 2) a practical view. In the first case, the intent is the definition of concepts or the proposal of mathematical models supporting companies willing to shift towards a more circular business. In the second case, the final aim is the description of best practices through case studies or the assessment of the sentiment of either companies or private citizens about circular economy effects, mainly through ad-hoc surveys (**Figure 2**). The following picture demonstrates that there is an unbalanced situation towards theoretical studies (theoretical and analytical assessment together) constituting 73.1% of the overall literature on circular economy and CBMs.

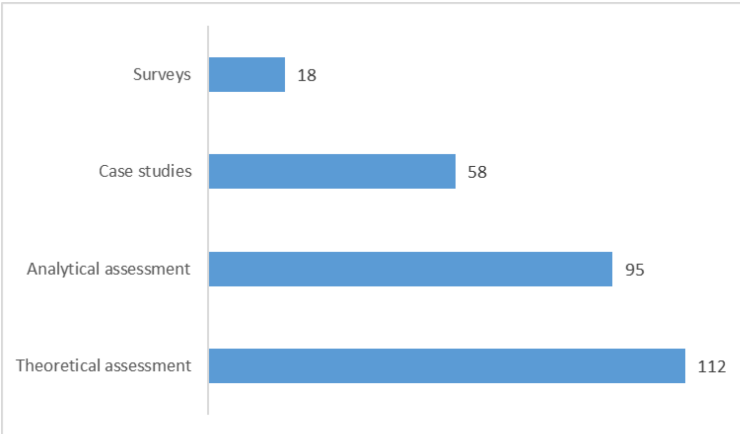

Figure 2: Main typologies of research

Then, considering the nationality of authors, it is possible to say that the highest number of contributions comes from northern European countries, followed by China and Italy. Considering the nationality of the articles' first author indicates United Kingdom as the major contributor, with 36 articles (19.6%), followed by Sweden (10.2%), The Netherlands (8.1%), China (6.0%) and Italy (4.9%) (**Figure 3**).

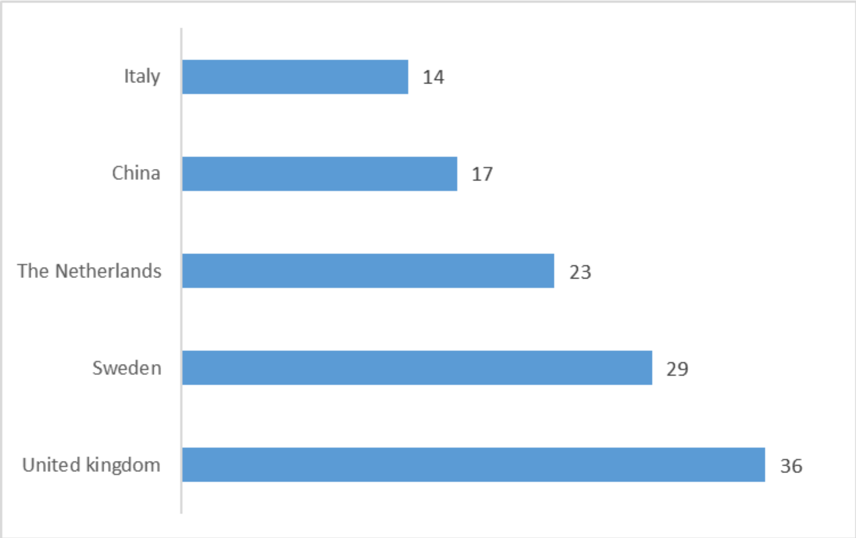

Figure 3: Top five publishing countries

Following an increasing level of detail about the typology of literature assessed, there are several perspectives from which circular economy and CBMs were approached by the experts. In macroscopic terms, business model design is the most discussed in literature (23.3%), followed by industrial strategies (20.1%), governmental policies (19.1%), environmental impact (11.7%), circular design of products (9.5% each), theoretical analyses (8.5%), societal impact (5.3%) and new technologies (2.5%) (**Figure 4**).

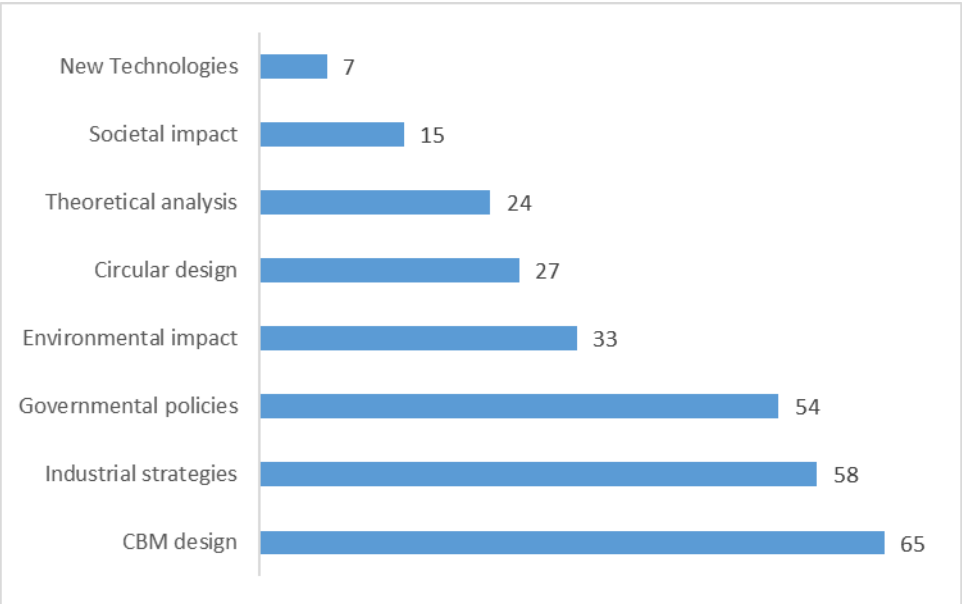

Figure 4: CE&CBM macro research areas

Increasing even more the detail of the literature assessment, there are several perspectives from which circular economy and CBM were approached. In microscopic terms, best practices are the most discussed topic in literature (10.2%), followed by opportunities and challenges related with circular economy (9.2%), conceptualization of circular economy (7.8%), BM innovation frameworks (7.4%), BM challenges and BM decision-support tools (6.0% each), Chinese CE policies, design decision-support tools and future trends (5.7% each). The sum of the mentioned topics represents about 50% of the available literature. Subsequently, a lot of other topics are discussed (**Figure 5**).

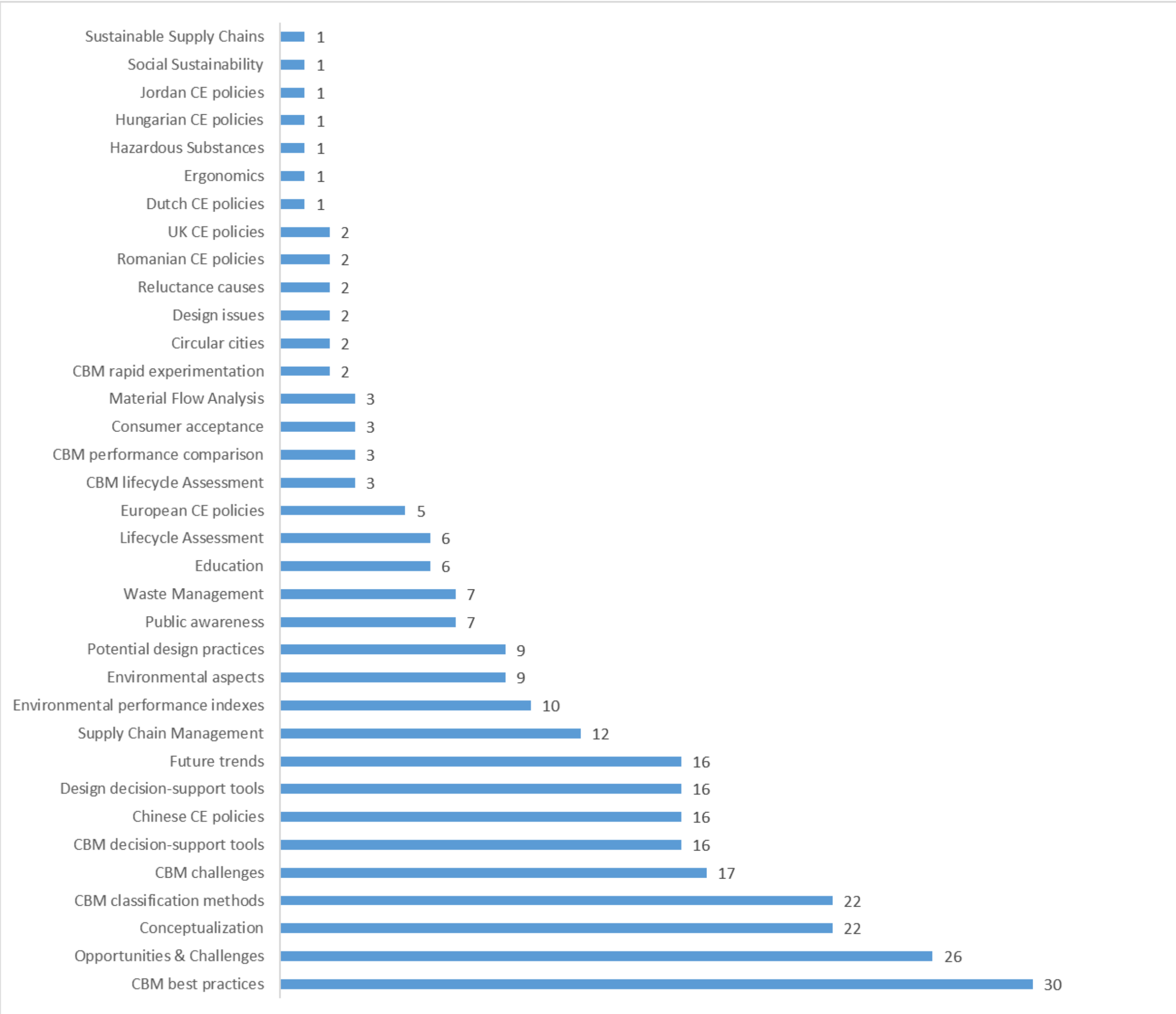

Figure 5: CE&CBM micro research areas

Concerning the mentioned topics appearing in **Figure 5**, only research areas strictly related with CBMs will be described into detail in the next paragraphs. A dedicated section (please, see section 2.2) will be focused on CBM classification methods.

The first, and most discussed, topic is related with CBM best practices, or practical implementation of CBMs. From this perspective, the authors follow different strategies. Some experts present CBMs by directly referring to existing examples, usually calling them with emblematic names. (Adam et al., 2017) speaks about repair cafés, second-hand shops, reversed retailing and reversed leasing, trying to interpret what already proposed by (The Ellen MacArthur Foundation, 2015) in terms of product life extension, resource recovery and product-as-a-service principles. (Whalen et al., 2017) presents two Swedish ICT 'gap exploiter' companies to provide a nuanced perspective in the investigation of ICT reuse business models and policies. Gap exploiters are third-party firms that create value through the re-utilization of existing products. Finally, (Prendeville et al., 2017b) focus their research on the critical role of makerspace managers/founders, recognised as gatekeepers to circular practices.

Others are focused on a certain kind of CBMs. For example, (Piciu, 2016) considers the role of circular business models in efficient and sustainable growth, by focusing on leasing models.

Some others are focused on a particular product. For example, (Bressanelli et al., 2017), (Bocken et al., 2017) and (Gnoni et al., 2017) propose dedicated case studies about the exploitation of pay-per-use BMs for washing machines.

However, great part of the literature focuses on a particular sector. (Hindley, 2016) describes the adoption of circular economy in the aluminium packaging industry in United Kingdom. (Kim et al., 2016) present environmental benefits reached by a South Korean steel manufacturer adopting circular economy principles. (Ma et al., 2014) follows the same logic in the same sector, but in China. (Laubscher et al., 2014) describes how the adoption of circular economy influenced the internal organization of a Dutch multinational company from the electric sector. (McIntyre and Ortiz, 2015) follows the same logic, but for an American multinational company from the ICT sector. (Rattalino, 2017) explores ways in which multinational corporations can pursue sustainability objectives while simultaneously embracing circularity principles, by presenting a case in the apparel sector. (Stål and Corvellec, 2018) describe seven Swedish companies adopting reuse business models in the apparel sector. (Sarasini et al., 2016) combines a business model perspective with insights from the Multi-Level Perspective and Technological Innovation Systems, by focussing on servitised mobility issues. (Svatikova et al., 2015) adopts the PSS strategy to the solar services sector. The intent is selling the service of providing the use of solar electricity to its customer instead of selling solar PV systems. (Jagger, 2016) describes a cyclical process combining electricity production from biomass with aquaculture and hydroponics like a good circular practice in United Kingdom. (Yazan et al., 2015) proposes a circular economy model where animal manure is used to produce biogas and alternative fertilizer, where the latter, in turn, is used in agricultural activities in a regional network of suppliers and producers. (Sousa-Zomer et al., 2017a) investigate the challenges faced by manufacturing firms when implementing pay-per-use business models and solutions adopted to overcome them. Finally, in (Sousa-Zomer et al., 2017b) the same PSS strategy is adopted to large white goods manufacturing.

Last but not least, other authors prefer to maintain a more generic perspective, proposing streamlines adoptable in any sector. (Beulque and Aggeri, 2016) focus on common patterns leading companies in reinventing their business models (e.g. strategic goals, incentives and recurrent challenges). (Dewberry et al., 2016) focuses on the opportunity for different types of product-people interactions to create new BMs that influence how redistributed manufacturing can support systems of circular resource flow. (Goyal et al., 2016) discusses about how Indian companies are coping with circular economy, by following reduce, reuse and recycling paradigms. (Guldmann, 2016) adopts the same logic, but for Danish companies. (Morioka et al., 2017) performs a comparison of competitive advantages – in terms of circularity levels – reached by eleven organizations from diverse sectors, situated in Brazil and in the United Kingdom. (Regenfelder et al., 2016) extracts the practice of innovators combining technological, organisational and business environment related innovation for closing the materials loop from industry evidence. (Venselaar and Kelft, 2014) describe a method to assist SME's to adopt reuse principles. Finally, (Scheel, 2016) proposes a sustainable wealth creation framework going to consider not only circular benefits for companies but also for communities, especially in developing countries.

The second research area about CBMs focuses on challenges related with the adoption of this new way of doing business. Also in this case, experts present different perspectives.

Some authors speak about CBM challenges from a general perspective, without considering any specific sector or issue. (Lüdeke-Freund and Dembek, 2017) reflects on the current state of the dynamically growing research and practice related to sustainable business models (SBMs),

motivated by the question of whether dealing with SBMs is just a passing trend or an emerging field, maybe even a field in its own right. (Roos, 2014) discusses the origins and meaning of different “green” concepts relevant for the circular value chain concluding with a high level definition. In addition, he outlines the process by which a business model for a circular value chain can be developed taking into account the social dilemma that exist in these type of situations. (Sannö et al., 2014) identify challenges and perspectives to be included in the development of environmental sustainability frameworks. (Smith-Gillespie, 2017) gives a working definition of CEBM. The definition presented here is one that attempts to balance the theory of circular economy with a practical, and practitioner-focused, perspective of business model design. (Morlat and Pinto-Silva, 2014) describes what are the market instruments for energy transition, and their relations with circular economy.
Some other authors prefer to describe CBM challenges from a macro level, referring to the concept of industrial symbiosis. One interesting example is given by (Chertow and Ehrenfeld, 2012), where a model involving numerous actors engaged in material and energy exchanges is presented, trying to map network benefits and institutionalize beliefs and norms enabling successful collaborative behaviours.
Others prefer to describe CBM challenges from a micro level, going at company level. For example, (de Lange and Rodić, 2013) explore the implications of a transition to a circular economy for solid waste management companies. Five new roles for waste management companies can be identified: 1) partner in reverse logistics (product take-back), 2) partner in product disassembly and remanufacturing, 3) partner in product design, 4) materials bank to enable intelligent materials pooling, and 5) miner of secondary resources from landfills and urban stocks. Again, (Franco, 2017) identifies a set of factors along the textile value chain, from product design to take-back and reprocessing, that are crucial in expediting or delaying a firm's aspirations to develop a circular product. (Guldmann and Jensen, 2015) analyse what the main challenges for companies working with circular economy are, and how companies overcome these. (Rizos et al., 2015); (Rizos et al., 2016) try to understanding about the barriers and enablers experienced by SMEs when implementing circular economy business models, looking first at the barriers that prevent SMEs from realising the benefits of the circular economy.
Some other authors prefer to focus on the role of Information and Communication Technology (ICT) in enabling circular economy. (Howell et al., 2017) examines the role of ICT advancements in frugal innovation and in influencing new business models. (Pagoropoulos et al., 2017) identify how can digital technologies support the transition to Circular Economy. (Planing, 2017) tries to answer the question whether the digital transformation of products, services and business models positively impacts the realization of a circular economy.
Others consider the relation of lean thinking with circular economy. (Kurilova-Palisaitiene et al., 2018) study how lean production could be used to tackle remanufacturing process challenges and contribute to shorter lead times. (Romero and Rossi, 2017) demonstrate the compatibility of circular economy and lean principles in the context of PSSs and contribute to their integration in order to create customer-oriented solutions that minimize resources consumption and enhance the ultimate value-added to the end-user.
The third research area about CBMs focuses on decision-support tools. Within this research stream, CMB classification methods presented in the next section 2.2 can be seen like a sub-group.
Some authors propose decision-support tools for improving the sustainability level of companies and make the transition towards circular economy easier. Several examples can be found in literature. (Bocken et al., 2013) develop a value mapping tool to help firms in creating value propositions better suited for sustainability. (Broman and Robèrt, 2017) follow a similar logic, by giving a comprehensive and cohesive description of their new Framework for Strategic Sustainable Development (FSSD). (Cong et al., 2017) presents an approach to find a profitable EOL strategy, which includes a method for generating a dismantling transition matrix and making decisions on the best dismantling sequence, level, and EOL options for components/parts. (Dolinsky and Maier, 2015) exploited a game theory tool (interactive decision theory) to suggest a quick market-based solution how to support circular economy business models whilst helping to the society to solve certain social

problems. (Inigo et al., 2017) examine the organisational processes of business model innovation for sustainability (BMIS) and provide a detailed analysis of how organisational and managerial capabilities for sustainability are utilised in business model innovation and transformation. (Xu et al., 2009) develops a systems dynamics and multi-objective programming model (SDMOP) for planning a regional circular economy. Various risk analyses are conducted using the technique of sensitivity analysis. (Zhao et al., 2017) propose a hybrid framework for evaluating the comprehensive benefit of eco-industrial parks from the perspective of circular economy.

Others develops decision-support tools able to solve a dedicated issue related with circular economy. For example, (Leising et al., 2018) develop a collaboration tool for managing circular buildings and related supply chain collaborations. (Lieder et al., 2017b) provide reliable decision support at the intersection of multiple lifecycle design and business models in the circular economy context to identify effects on cost and CO2 emissions. (Panarotto et al., 2017) present a simulation framework for circular design of PSS. The simulation process enables the comparison between functional and non-functional performances and their life cycle contributions depending on a defined PSS-like business model strategy.

Other authors focus on a specific type of CBM. (Gharfalkar et al., 2016) try to understand inconsistencies and/or lack of clarity that exist between the definitions or descriptions of identified reuse options and propose different reuse-based business models. (Marconi et al., 2017) proposes a web-based platform to implement reuse scenarios for electronic components. The objective is to create a structured portal where all the stakeholders can collaborate to extend the components lifespan and implement new circular business models.

Others prefer to follow a comparison strategy between circular economy-related behaviours/tools and linear ones. (Reigado Rodrigues et al., 2017) analyse existing CE toolkits versus the PSS methodology, trying to characterize the relation between each stage of the methodology and each objective of the toolkit. (van Loon et al., 2017) explore the role of the second-hand market when transitioning to a closed-loop system where products are leased multiple times. The total cost of ownership for consumers and profitability for manufacturers are compared in circular and linear business cases. (van Loon and Van Wassenhove, 2017) develop a simple tool suppliers can use to quickly assess whether remanufacturing is economic and environmentally attractive compared to producing new components.

Other research areas related with CBMs that can be found in literature are those focused on CBM lifecycle assessment, CBM performance comparison and CBM rapid experimentation. Unfortunately, all of these topics are taken into account by very few authors. This way, it is impossible to have a general picture of these research areas.

In the first case, CBM lifecycle assessment is proposed by just three authors and in three completely different ways. (N. Bocken et al., 2016) proposes a list of guiding principles to start assessing the impact of new circular business models. The guiding principles are organised according to the following high-level strategies: Slowing effects; Closing effects; Life cycle effects, and Systems effects. (Pal and Gander, 2018) examine and categorize the different sustainability activities of firms in the fashion industry. Based on this analysis a number of propositions are developed that can be used to test whether emerging ways of producing and distributing fashion garments have the potential to become the foundation of more sustainable business models. Finally, (Popa and Popa, 2017) develop a new conceptual framework for business process modelling and analysis using circular economy innovative theory as a source for business knowledge management.

The description of CBM performance assessment follows the same logic like before. (Morioka et al., 2016) discusses the sustainability performance of the circular business models (CBM) necessary to implement the concept on an organisational level with two case studies - an office furniture remanufacturing operation, and an aluminium sheet manufacturer - from a value-based perspective. (Piscicelli et al., 2018) examines an emerging and innovative type of sustainable business model based on the peer-to-peer (P2P) sharing of underutilised assets facilitated by digital platforms. In addition, they investigate the values of users of a successful P2P goods-sharing platform and to what extent they differ from values of users of a comparable, yet unsuccessful, platform. Finally,

(Vogtlander et al., 2017) propose an Eco-efficient Value Creation method to analyse innovative product and service design together with circular business strategies. The method is based on combined analyses of the costs, market value (perceived customer value) and eco-costs. This provides a prevention-based single indicator for 'external environmental costs' in LCA.
In the third case, CBM rapid experimentation is described uniformly by all the authors. (Antikainen et al., 2017) try to understand how to design circular business model experimentation that takes into consideration both the companies' and the research organizations' needs. Finally, (Bocken et al., 2018) present an in-depth case study of a large international clothing retailer embarking on a journey of business model experimentation for circularity: the processes, methods, roles and the organisation in light of the need to address broad sustainability challenges in the business.

2.2. Current state of the art on CBM classification methods

Considering only the literature about CBM classification methods, the number of articles to be taken into account is limited to 21 papers. In general terms, it is possible to distinguish these works in three macro segments: 1) papers referring to the ReSOLVE framework proposed by (The Ellen MacArthur Foundation, 2015), 2) papers referring to the Business Model Canvas (BMC) methodology proposed by (Osterwalder and Pigneur, 2010) and 3) papers proposing hybrid models, exploiting both the previous ideas – see **Table 1** for details.

Author	CBM classification method								
	ReSOLVE	BMC	SI	PPP	OS	CD	BSC	VEM	MM
(Antikainen and Valkokari, 2016)		x							
(Nerurkar, 2017)			x						
(Bocken et al., 2014)						x			
(Nussholz, 2017a)		x							
(Nussholz, 2017b)		x							
(Charter, 2016)	x								
(Lozano et al., 2016)				x					
(Tolio et al., 2017)					x				
(Lewandowski, 2016)		x							
(Heyes et al., 2018)	x	x							
(Manninen et al., 2018)	x								
(Morioka et al., 2018)								x	
(Mendoza et al., 2017)	x								
(Janssen and Stel, 2017)							x		
(N. M. P. Bocken et al., 2016)						x			
(Haanstra et al., 2017)									x
(Stratan, 2017)		x							
(Prendeville and Bocken, 2016)						x			
(Witjes and Lozano, 2016)				x					
(Urbinati et al., 2017)		x							
(Chiappetta Jabbour et al., 2017)	x								
(Chiaroni et al., 2016)		x							
BMC= Business Model Canvas; SI= Sustainability Impact; PPP= Public-Private Partnership; OS= Operation Strategy; CD= Circular Design; BSC= Balanced Score Card; VEM= Value Exchange Matrix; MM= Morphological Matrix									

Table 1: Main CBM classification methods

The ReSOLVE framework is a set of principles defined by (The Ellen MacArthur Foundation, 2015) focused on supporting companies and governments during the definition of circular economy policies. This framework identifies six different ways to be circular like: a) Regenerate, b) Share, c) Optimize, d) Loop, e) Virtualize and f) Exchange. Within the "Regenerate" group there are actors focused on: 1) shifting on renewable energy and materials, 2) reclaiming/retaining/restoring health of the ecosystem or 3) returning recovered biological resources to the biosphere. Within the "Share" group there are actors focused on: 1) sharing assets, 2) reuse/second hand or 3) prolonging product lifetime through maintenance/DfX rules. Within the "Optimize" group there are actors focused on: 1) increasing performance/efficiency of products, 2) removing waste in production and supply chains or 3) leveraging big data, automation, remote sensing and steering. Within the "Loop" group there are actors focused on: 1) remanufacturing of products/components, 2) recycling of materials, 3) anaerobic digestion of wastes or 4) extraction of biochemicals from organic wastes. Within the

"Virtualize" group there are actors focused on direct/indirect dematerialization of products. Within the "Exchange" group there are actors focused on: 1) replacing old materials with advanced non-renewable ones, 2) application of new technologies or 3) transformation of products/services.

Even if the ReSOLVE framework cannot be referred as a real classification method, many experts start from it to develop their own classification methods. (Charter, 2016) initially distinguishes CBMs in two macro classes, like disruptive and hybrid/incremental. Then, he identifies six different sub-segments: 1) produce on demand, 2) dematerialization, 3) product life-extension, 4) reuse/remanufacture/recycle, 5) PSS, 6) sharing economy/collaborative consumption. These last categories try to translate in practical terms what theoretically defined by the ReSOLVE framework. (Manninen et al., 2018) exploit the ReSOLVE framework to develop an environmental value proposition table (EVPT). The EVPT brings out that environmental values can be considered as absolute values of the business models, by presenting concrete value propositions of CE business models under the different CE business model categories. (Mendoza et al., 2017) adds to the original ReSOLVE framework the "Implement" level, trying to reduce the gap between the theoretical principles presented and their practical adoption. This way, a new iReSOLVE framework is proposed. Finally, (Chiappetta Jabbour et al., 2017) start from the ReSOLVE framework to map the relation between CBMs and big data analysis. Considering the BMC-based classification methods, some interesting perspectives are offered by the authors. In general terms, papers pertaining to this category try to modify the original BMC up to make it able to map also circular business models and not only linear ones. A first example is offered by (Antikainen and Valkokari, 2016). Here, the authors add to the original BMC other two evaluation levels (ecosystem and sustainability) with the intent to better map all the existing links between a reference company and all the actors involved in its supply chain. Another perspective is given by two works of (Nussholz, 2017a)(Nussholz, 2017b). Here, the author embeds in the original BMC a method to assess the added value coming from a cyclical exploitation of resources. This way, the BMC is replicated for each of the three phases of a product lifecycle (e.g. BOL, MOL and EOL). Again, (Lewandowski, 2016) adds to the original BMC two dimensions, like take-back system and adoption factor, trying to map also CBMs with the same model. (Stratan, 2017) has a similar intent, but a different perspective. The author adds to the original BMC the social entrepreneurship side for making it able also to assess not-for-profit businesses. Finally, (Chiaroni et al., 2016); (Urbinati et al., 2017) focus on two specific BMC elements, like value proposition and relations with suppliers. These two elements are considered by the authors like the most important KPIs to control when a circular economy strategy has to be implemented. Considering papers proposing hybrid models, also in this case some interesting perspectives are presented by the authors. (Nerurkar, 2017) classifies sustainability impacts related with CBMs in four classes: 1) environmental 2) social, 3) financial and 4) mixed. (Bocken et al., 2014) propose a set of CBM archetypes starting from circular product design principles. (Lozano et al., 2016)(Witjes and Lozano, 2016) identify in their works how the relation between public and private sectors is essential for the development of circular economy strategies. (Tolio et al., 2017) focus on the operational issues related with CBM implementation strategies and information exchange among actors involved in circular value chains. (Heyes et al., 2018) put together BMC and ReSOLVE trying to map service-oriented companies. (Morioka et al., 2018) do a similar thing, but for assessing an entire business model through a sustainable value exchange matrix (SVEM). (Janssen and Stel, 2017) map the sustainability of the value proposition through a redefinition of the balanced score card (BSC). (N. M. P. Bocken et al., 2016) try to classify CBMs basing on the concept of resource flows. This way, CBMs are classified into three groups: 1) those prolonging product lifecycle, 2) those closing material loops and 3) those reducing material consumption. (Haanstra et al., 2017) propose a morphological matrix linking product lifecycle stages with organizational procedures. Finally, (Prendeville and Bocken, 2016) propose the service design like a fundamental element supporting circular economy practices.

ReSOLVE and BMC are the most popular ones, followed by the others. For this reason, also within the FENIX project the ReSOLVE framework and the BMC method will be taken into account like the two reference classification methods for CBMs. In particular, the ReSOLVE framework will be taken into account for the identification of CBM archetypes at macro level. Then, during the exploitation of results (WP6), the BMC method will be adopted for the detailed description of the identified CBMs at micro level.

2.3. Current CBMs proposed in literature

The assessment of the available literature on CBMs and CE, from the perspective of what are the most discussed CBMs, produced the results depicted in **Table 2**. The CBMs macro classification adopted is the common ReSOLVE framework constituted by six classes. On the other hand, the micro classification was adapted from the last OECD's report on circular business models and it is composed by fourteen classes considering the full amount of different business models related with circular economy existing in literature. The "Regenerate" class embeds those CBMs related with renewable energy, bio-based and secondary materials exploitation instead of traditional production inputs. This way, adopting firms can reduce the environmental pressures emanating from their supply chains, while ensuring that the materials embedded in their products do not eventually become waste. The "Share" class is constituted by CBMs related with sharing either the ownership or the access to some resources. Within this classification there are mainly five elements: co-ownership, co-access, use-oriented PSSs, reuse and repair. The co-ownership involves the lending of physical goods, especially those capital intensive, infrequently used, and having a low ownership rate. The co-access, instead, involves allowing others to take part in an activity that would have taken place anyway. A typical example is carpooling. Use-oriented PSSs can be considered like sharing CBMs. Customers pay for temporary access to a particular product, typically through a short- or long-term lease agreement, while the service provider retains full ownership of the product. Reuse occurs when wasted products can be directly reused either by other actors or in other sectors. Finally, repair occurs when products need to be repaired before reusing them. The "Optimize" class considers together those CBMs related with the reduction of wastes within supply chains. There are two ways to do it. First, industrial symbiosis involves the reuse of by-products from one firm as input material by another. This way, resources can stay within the economy for more time. Second, it could be possible to extend the lifetime of products just adding after-sale (or product-oriented) services on them, like maintenance or reconfiguration. The "Loop" class groups together CBMs focused on refurbishing/remanufacturing and recycling. In the first case, products can be refurbished or remanufactured before reusing them. This step is often done to reset the lifetime of products or adding new functionalities on them. In the second case, products are recycled to recover secondary raw materials. This process involves three main activities, each of which is typically undertaken by different market actors: collection, sorting and secondary production. After collection of the wasted materials, sorting acts the separation of a particular waste stream into its constituent materials. Then, secondary production involves the transformation of sorted waste material back into finished raw materials to be sold into the market. Based on the final market of secondary production, there are two different businesses: recycling and industrial symbiosis. Recycling involves the transformation of waste into secondary raw materials to be sold in the materials market. Depending on the quality of recovered materials compared with virgin ones, it is possible to speak also about downcycling (low quality) or upcycling (high quality). The "Virtualize" class embeds those CBMs focused on reducing the exploitation of resources through dematerialization of products and/or processes. Even if dematerialization of products is not well-assessed in literature (no articles were found), a promising way to dematerialize processes is represented by result-oriented PSSs. This way, customers will pay for a service, not for a product. Finally, the "Exchange" class considers those CBMs exploiting key enabling technologies instead of common ones during their production processes. The final intent is the improvement in sustainability. A typical example is the adoption of Additive Manufacturing (AM).

Author	Circular Business Models														
	Regenerate		Share					Optimize		Loop		Virtualize		Exchange
	Renewable energies	Bio- / Secondary materials	Co-ownership	Co-access	Use-oriented PSSs	Reuse	Repair	Industrial Symbiosis	Product-oriented PSSs	Refurbish / Remanufacture	Recycling	Result-oriented PSSs	De-materialize	New technologies
(Adam et al., 2017)					x	x	x							
(Beulque and Aggeri, 2016)											x			
(Bradley et al., 2016)		x								x	x			
(Braungart et al., 2007)		x						x			x			
(Bressanelli et al., 2017)					x									
(Broadbent, 2016)											x			
(Bocken et al., 2017)					x									
(Buil et al., 2017)											x			
(Chertow and Ehrenfeld, 2012)								x						
(Cong et al., 2017)											x			
(Dalhammar and Milios, 2017)						x				x				
(de Lange and Rodić, 2013)		x								x	x			
(De los Rios and Charnley, 2017)					x				x			x		
(Dewberry et al., 2016)							x							
(Di Maio and Rem, 2015)											x			
(Dolinsky and Maier, 2015)						x				x	x			
(Favi et al., 2017)		x									x			
(Frenken, 2017)			x	x										
(Frone and Frone, 2017a)								x						
(Frone and Frone, 2017b)								x						
(Geng and Doberstein, 2008)											x			
(Gharfalkar et al., 2016)						x								
(Ghisellini et al., 2016)						x					x			
(Giurco et al., 2014)											x			x
(Gnoni et al., 2017)					x									
(Goyal et al., 2016)						x					x			
(Guldmann, 2016)						x					x			
(Hagelüken et al., 2016)											x			
(Hartwell and Marco, 2016)										x				
(Heyes et al., 2018)												x		
(Hu et al., 2011)		x												
(Jagger, 2016)	x	x						x						

(Jawahir and Bradley, 2016)		x									x			
(Kurilova-Palisaitiene et al., 2018)										x				
(Landaburu-Aguirre et al., 2016)						x					x			
(Leslie et al., 2016)						x					x			
(Li et al., 2010)	x							x						
(Lieder et al., 2017a)					x	x								
(Lieder et al., 2017b)						x				x	x			
(Liguori and Faraco, 2016)		x												
(Linder and Williander, 2017)					x				x	x		x		
(Lindström, 2016)					x				x			x		
(Lofthouse et al., 2017)										x				
(Malinauskaite et al., 2017)	x													
(Marconi et al., 2017)						x								
(Mathews and Tan, 2011)								x						
(Maxwell et al., 2006)					x				x			x		
(Mendoza et al., 2017)					x				x			x		
(Milios, 2017)						x					x			
(Molina-Moreno et al., 2016)	x	x												
(Morioka et al., 2016)										x				
(Mosquera-Losada et al., 2017)		x												
(Mugge et al., 2017)										x				
(Nystrom et al., 2017)					x				x			x		
(O'Connor et al., 2016)											x			
(Pagoropoulos et al., 2017)					x				x			x		
(Pan et al., 2015)	x							x						
(Panarotto et al., 2017)					x				x			x		
(Piciu, 2016)					x									
(Piscicelli et al., 2018)			x	x										
(Prendeville and Bocken, 2016)					x				x			x		
(Prendeville et al., 2017a)			x	x										
(Prendeville et al., 2017b)			x	x										
(Rashid et al., 2013)										x				
(Rattalino, 2017)		x												
(Regenfelder et al., 2016)											x			
(Reigado Rodrigues et al., 2017)					x				x			x		
(Ribeiro de Oliveira et al., 2017)								x						
(Ripanti et al., 2016)										x				

H2020 Innovation Action - This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 760792

(Romero and Molina, 2012)								x						
(Romero and Rossi, 2017)					x				x			x		
(Roos, 2014)								x						
(Sahu et al., 2016)		x												
(Sarasini et al., 2016)												x		
(Sarkis et al., 2010)											x			
(Scheel, 2016)		x												
(Scheepens et al., 2016)												x		
(Schroeder et al., 2018)											x			
(Sheldon, 2016)	x	x												
(Smol et al., 2015)		x												
(Sousa-Zomer et al., 2017a)					x									
(Sousa-Zomer et al., 2017b)					x									
(Spring and Araujo, 2017)					x		x		x			x		
(Stål and Corvellec, 2018)						x								
(Svatikova et al., 2015)					x									
(Testa et al., 2017)											x			
(Tolio et al., 2017)										x	x			
(Tyl et al., 2006)						x	x							
(van Loon et al., 2017)					x									
(van Loon and Van Wassenhove, 2017)										x				
(Venselaar and Kelft, 2014)						x								
(Virtanen et al., 2017)		x									x			
(Vogtlander et al., 2017)					x				x			x		
(Wen and Meng, 2015)								x						
(Whalen et al., 2017)						x								
(Yazan et al., 2015)	x	x						x						
(Zeng et al., 2017)								x						
(Zhao et al., 2017)								x						
(Zuidema, 2014)			x	x										
(Zvarych, 2017)											x			
Total	**7**	**17**	**5**	**5**	**23**	**17**	**4**	**15**	**13**	15	**29**	**16**	**0**	**1**

Table 2: Circular Business Models described in literature (adapted from (The Ellen MacArthur Foundation, 2015)**;** (OECD, 2017)**)**

Considering what reported in the previous **Table 2**, some information can be gathered about the current focus of CBM literature and existing gaps. Just numbering the amount of articles basing on reference CBM classes, it is possible to see that some types of CBMs are more frequently taken into account than others. For example, the most common BMs described in literature when speaking about CE are represented by recycling practices and use-oriented PSSs. Then, there are other BMs widely considered like a real application of CE. These are focused on bio-based / secondary materials exploitation, reuse and refurbishing / remanufacturing practices, result-oriented and product-oriented PSSs and industrial symbiosis. Finally, there are other CBMs not so commonly described in literature. These are focused on renewable energies, co-ownership and co-access, repair practices, product dematerialization and new technologies.

What is evident from the presented literature is that there is a big research gap in terms of new ideas on how practically transform a linear business model in a circular one. Just in very few cases the experts present innovative ideas and implement them in practice. From one side, theoretical concepts are given usually like a suggestion to companies and politicians, without explaining the logical procedure to follow for their implementation. From another side, best practices are described like a complex mix of mechanisms not always comprehensible and adoptable by a general public. Again, the involvement of common people in current industrial CBMs is almost absent from the reference literature. The FENIX project tries to fill in these research gaps through a practical implementation of different CBMs that will be selected within the present WP1. The final intent is proposing a practical way of enabling all companies that are willing to adopt really circular practices.

3. INDUSTRIAL BENEFITS ANALYSIS

After having defined the type of CBM classification method to be exploited within FENIX, the subsequent activity was the identification of industrial benefits. In other words, our interest was the comprehension of what are the most important benefits expected by companies when approaching a circular economy strategy. Also in this case, a state of the art analysis was implemented, going in listing what are the most common benefits described in literature. However, the literature assessment was supported also by a set of direct interviews with all of the FENIX partners, both in person and by phone/teleconference. The aggregation of these two views allowed us to select the list of the main benefits expected by the FENIX project.

3.1. Current state of the art on industrial benefits

The intent of this section is the analysis of the state of the art to detect the most important benefits expected from the adoption of circular practices within companies.
So far, some articles already proposed and listed these sustainable benefits, based on both theoretical assessments and practical evidences. Therefore, a study has been performed to gather, list and classify them, also keeping in account the triple bottom line perspective of sustainability (economic, environmental and social) (WCED, 1987). Grounded on this appraisal, these benefits have been then grouped and gathered in macro categories in order to enable industrials to easily detect the main benefits they expect to reach through the adoption of a Circular Business Model (CBM).
A relevant contribution was given by (Schaltegger, Lüdeke-Freund and Hansen, 2011). First, he defined the concept of business case for sustainability. It has the purpose to create economic success with a voluntary intention to contribute to environmental and social issues: both these aspects are led by the support of a certain and structured management activity. Based on this concept, they proposed the core drivers of a business case for sustainability:

- Costs and cost reduction (Epstein, 1996; Christmann, 2000)
- Sales and profit margin (Porter and Van der Linde, 1995; Porter and Van Der Linde, 1995)

- Risk and risk reduction (Schaltegger and Wagner, 2006)
- Reputation and brand value (Jones and Rubin, 2001)
- Attractiveness as employer (Ehnert, 2009; Revell, Stokes and Chen, 2010)
- Innovative capabilities (Pujari, 2006; Cohen and Winn, 2007; Schaltegger and Wagner, 2011).

Among these drivers, (Collins, Roper and Lawrence, 2010) identified as the most important for moving towards an environmental and social direction the reputation and brand, employees' demands, risk management and potential cost reductions. In particular, cost reductions (e.g. through resource efficiency) are seen as the most promising driver, followed by aspects such as dealing with regulatory risks, attracting and retaining staff, attracting new customers and increasing market share, as well as attaining good publicity.

(Schaltegger, Lüdeke-Freund and Hansen, 2011) also dealt with the links existing between environmental and social activities and companies' success from an economic point of view, trying to explain how these links can be managed, enhanced or renewed in order to improve economic outcome through voluntary social and environmental activities. They also introduced four business model pillars (value proposition, customer view, infrastructure and network of partners, financial aspects), through which the logic of companies in general terms could be described. They found it is essential to understand and manage the links of these pillars with the core drivers of a business case for sustainability to be able to evaluate the innovation degree needed in terms of business model to move towards sustainability (see **Figure 6**).

	Generic business model pillars			
Core drivers of business cases for sustainability	Value Proposition (VP)	Customer relationships (CR)	Business infrastructure (BI)	Financial aspects (FA)
Costs and cost reduction	Products and services with lower energy or maintenance costs for customers	Cost-efficient contracting relationships, closed-loop service systems	Costs of new products and services can be lowered through partnerships	Balancing cost reductions for customers and cost structures of new products and services to increase profitability
Sales and profit margin	Environmentally and socially superior products and services require modified or new VPs to turn into sales and profits	Higher customer retention and cu-stomer value as a result of sustainability-oriented, service-intense relationships	New products and services may require strategic partnerships (e.g. co-opetition) to overcome market barriers	New products and services and/or new customer relationships contribute to diversified revenue streams
Risk and risk reduction	Lowering societal risks through products and services can create value to certain customer segments	Service-relationships reducing sustainability risks for customers result in higher customer loyalty	Resources, activities, and partnerships set up in order to minimize internal and external risks	Improved risk and credit rating resulting from lowered sustainability risks
Reputation and brand value	Sustainability as distinctive element of good corporate reputation	Sustainability as marketing feature of the brand increasing customer loyalty	Strategic partnerships with sustainability leaders can increase reputation and brand value	Sustainability performance leading to a good rating and the consideration in sustainability indices and funds
Attractiveness as employer	A companies' offerings and VPs allowing for personal identification to attract employees	Better customer service as a result of higher employee motivation	Attractiveness as principal can enhance the quality of activities, resources, and partnerships	Reduced costs for HR acquisition, less fluctuation costs and lower compensation costs
Innovative capabilities	Unfolding the full sustainability-potential of inno-vations enables modified or new VPs	Innovative products and services creating solutions to sustainability problems, improving customer retention	To allow for innovations to unfold may require new activities, resources, and partnerships	Higher innovation potential and expectations for profitable innovations leading to an increase of shareholder value

Figure 6: Interrelation between BM and business case drivers (Schaltegger, Lüdeke-Freund and Hansen, 2011)

As a result, they found that to address each driver based on the sustainability strategy chosen, requires different degrees and characteristics of business model.

(Park, Sarkis and Wu, 2010) investigated the challenges and opportunities of how firms and organizations can and will be able to strike a better balance between economic growth and environmental stewardship in the context of China's emerging 'circular economy' policy paradigm. They identified, based on three company case studies in the information technology and electronic industries in China, four ways by which the environmental and economic value can be created, supported by the adoption of a sustainable supply chain management. First, reduce cost through sustainable supply chain management. Second, generate new revenue streams through a more effective life cycle management of ICT products (recycle ICT products and materials generating from these streams a substantial revenue stream). Third, provide organizational and supply chain resiliency through environmentally sound management practices (enhancing the availability of materials as well as maintaining the supply channels). Fourth, enhance the regulatory compliance through environmentally sound management practices and ICT supply chain management.

(Roos, 2014) discussed about business model innovation. He stated that the business model is composed of a set of dimensions and that business model innovation requires an innovation in at least one of these dimensions. Then, he proposed a framework for green value creation and realization (see **Figure 7**).

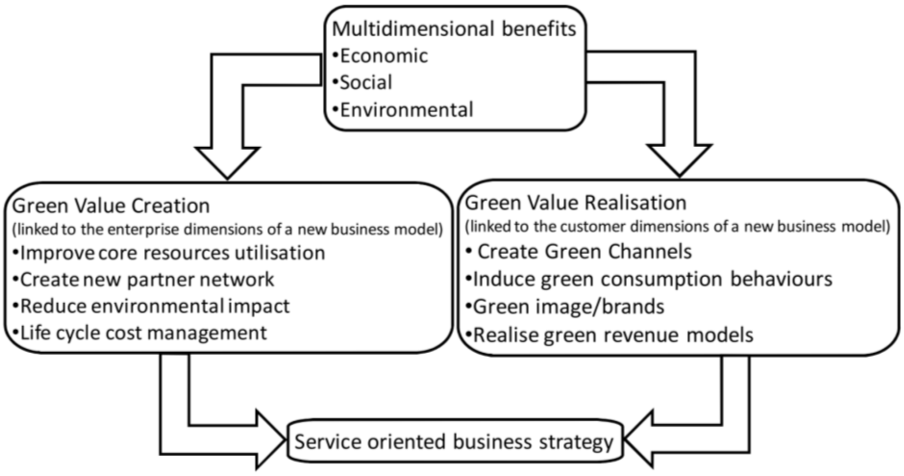

Figure 7: Multi-dimensional benefits (Roos, 2014)

Indeed, according to (Roos, 2014), green value creation faces two linked problems that have to be simultaneously addressed: the green value creation itself and the green value realization. This means creating multidimensional value for stakeholders (improving core resources utilization, creating new partner networks, reducing environmental impact and implementing a life cycle cost management) and that of appropriating the largest possible share of the monetary equivalent of this value from the paying customer or paying stakeholders (creating green channels, inducing green consumption behaviors, developing green image/brands and realizing green revenue models). This normally requires manufacturing firms to move towards servitization, adopting a service oriented approach.

More specifically, (Roos, 2014) stated that to solve these two problems and constructing a successful business model, at least one valuable problem-solution pair (waste related situations that are costly and that could be solved at a lower cost than keeping the present state) should be identified. The second prerequisite for an economically sustainable business model is that there exists a way for the firm to appropriate a large enough share of the created value. He raises also the attention to a complication in the waste domain: many of the problem-solution pairs are of the social dilemma type. This means that individuals in interdependent situations face choices in which the maximization of short-term self-interest conducts to outcomes that leave all the participants in worse conditions than any feasible alternatives. For this reason, in these types of social dilemma situations, valuable problems may not be perceived as opportunities by firms since the created value is dispersed among all problem-owners and from many of which the firm is not able to capture any value.

Related to this, (McKinsey Global Institute, 2011) identified resource related value creation levers for businesses (see **Figure 8**), grouping them in three macro areas: growth, return on capital and risk management. Growth comprises new markets (a better understanding of resource-related opportunities in new market segments and geographies), innovation and new products (to fill needs of customers and company and composition of business portfolio (based on resource trends)). Return on capital proposed green sales and marketing (improved revenue through increased share and/or price premiums by marketing resource-efficiency attributes), sustainable value chains (improved resource management and reduced environmental impacts along the value chain to reduce costs and improve the value proposition) and sustainable operations (reducing operating costs through internal resource management). Risk management is instead divided in regulatory management (mitigating risks from regulation), reputation management (getting credits and reducing reputation risks through proper stakeholder management) and operational risk management (managing risk of operation disruptions from resource scarcity, climate change impacts or community risks).

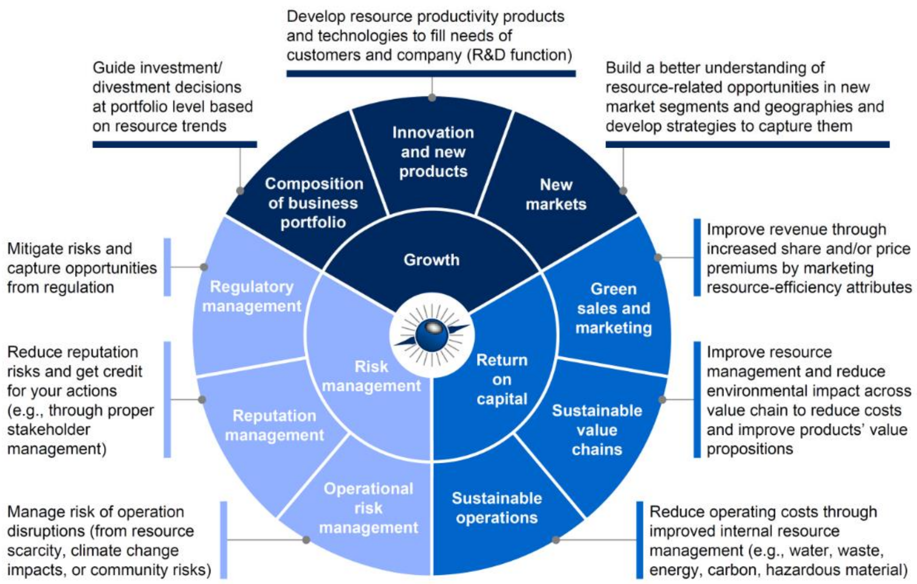

Figure 8: Resource-related value creation levers (McKinsey Global Institute, 2011)

Since, at the micro level, several firms across different industries have unveiled their intentions to move towards circularity by implementing cleaner production and eco-design initiatives, (Franco, 2017) conducted an inductive qualitative study to investigate circular economy at this level. He highlighted that the number of component parts in a product and the availability of their ecological alternatives in the market posed an initial challenge for firms that ventured into circular production models. Complexity in product components refers to the number of components a product design contains that need to be specified and produced or procured (Novak and Eppinger, 2001). Based on this consideration, he found that the development of basic materials and component parts plus the demand inducement from well-located players in the supply chain appeared to define the relative availability of circular products in the market.

(Sannö et al., 2014) detected the main challenges and perspectives composing an environmental sustainability framework. They detected four sub-research categories on which this framework is based:

- resource efficiency;
- enablers for change and innovation;
- circular business model research;
- emerging sustainable technologies (including product and production ones).

A major focus can be done on the first two streams. In particular, resource efficiency can be achieved in different ways:

- performing closed loop energy mapping;
- developing a CO2 neutral life cycle of the products;
- understanding different market needs for efficiency;
- identifying relevant measure on the resource efficiency for organizational monitoring on improvements and to facilitate decision making;
- evaluating climate impact from construction in different regions and how to avoid them by deploying best practices;
- developing resource efficiency in products –optimized machines dependent on how and where it operates;
- developing resource efficiency in production i.e. innovative sustainable production techniques, regeneration of energy in production, efficient use of machines on site management level;
- developing resource efficiency in transport and logistic;
- optimizing the fleet and site management based on energy efficiency;
- exploring the environmental impact consequences of increased local production in modular approach;
- developing trainings in practicing energy efficiency.

Some enablers to be considered for change and innovation towards environmental sustainability can be for example exploring facilitators to make the sustainable technologies to reach the markets, increasing the knowledge and state of the art practices upon sustainable alternative solutions, understanding how to change behaviors and drivers of mind-set change, promoting and performing communication strategies for environmental care. (de Lange and Rodić, 2013) found that at least three aspects have to be considered to shift towards circular economy:

- product design and manufacturing, managing resources more efficiently through technical and biological cycles;
- business models, introducing product-service systems (customers pay for performance and producers keep the ownership of their products);
- nature of relationships between and among stakeholders, enabling circular value chains through collaboration and long-term relations.

Based on these three aspects, delineating how to perform a transition towards circularity, they also defined which actions should be practically performed in product manufacturing:

- Eco-effectiveness paradigm: enhancing positive impact, increasing asset value of end-of-life products;
- Simpler products, easy to disassembly;
- Pure materials;
- Substances with known and healthy properties;
- Secondary resources;
- Powered by renewable energy sources.

(Rizos et al., 2016) investigated the barriers and the enablers for SMEs in their attempt to set up a circular economy business model. Among the main results, saving material costs, creating competitive advantages and new markets are the main reasons for European SMEs to take action in this sense. On the other side, among the enablers of this shift the most mentioned is the company culture of the staff and manager: indeed, for start-up companies it is easier to adopt circular economy principles, since they don't have to change consolidated practices as in existing firms.
Others enablers are: networking (joining a group of like-minded SMEs striving for sustainability, or membership of a supply chain partnership), support from the demand network (customers prefer green products or services), proposing a financially attractive business model, external recognition of green business models, personal knowledge in the company and government support.

(Romero and Rossi, 2017) aimed to contribute to the creation of customer-oriented solutions that minimize resources consumption and enhance the ultimate value-added to the end-user. To do this, they attempted to demonstrate the compatibility of circular economy and lean principles in the context of PSSs. They proposed Circular Lean PSS to support and foster the accomplishment of three main principles:

- Preserve and enhance natural capital "by controlling finite stocks and balancing renewable resources flows";
- Optimize resource yields "by circulating products, components, and materials at the highest utility at all times in both the technical and biological cycles".
- Foster system effectiveness "by revealing and designing out for negative externalities". PSSs link tangible (product) and intangible (services) components to achieve higher customer value delivery, but also to increase value for the whole society.

Based on the analysis of the literature conducted above, the detected benefits have been categorized based on the three levels of sustainability (economic, environmental and social) and then grouped and gathered in macro categories in order to enable industrials to easily detect the main ones they expect to reach through the adoption of a Circular Business Model (CBM).

In the following, a table connects the authors to the benefits they raised to be enabled by CBM. Then, a brief explanation of each of the benefits detected is reported.

1. Economic:
    a. Reducing overall costs: Sales and profit margin improvement.
       It consists in reducing costs concerning both the products and the processes needed for their production and delivery, starting from the cost of resources up to its transport. In this context the reduced costs are also considered mainly for the providers, but also for customers during the use, service delivery and disposal phases of the product/service lifecycle. For example, lower energy or maintenance costs of products and services, cost-efficient contracting relationships or costs of new products and services lowered through partnerships can be considered in this category.
       Also the sales and profit margin can be improved: a solution could be balancing cost reductions for customers and cost structures of new products and services to increase profitability. This way, customer retention and customer values will increase. New products and services may require strategic partnerships (e.g. co-opetition) to overcome market barriers. New products and services and/or new customer relationships contribute to diversified revenue streams.
    b. Reducing business risks: it can be achieved through reputation management (getting credits and reducing reputation risks through proper stakeholder management) and operational risk management (managing risk of operation disruptions from resource scarcity, climate change impacts or community risks).

Risks can be reduced through products and services that can create value to certain customer segments. Service-relationships can reduce sustainability risks for customer's result in higher customer loyalty. Resources, activities and partnerships can be set up in order to minimize internal and external risks.

c. Opening new revenue streams: it can be achieved through effective life cycle management of ICT products and of internal resources. Also, the business portfolio can be configured based on resources trends.
d. Reducing product/process complexity: complexity in product is reduced through the number of components needed to be specified and produced or procured. In this way, also the level of modularity of the product is enhanced. The development of basic materials and component parts plus the demand inducement from well-located players in the supply chain appeared to define the relative availability of circular products in the market.
e. Improving competitive advantage: innovations (in terms of new products, functions, services and business models) can be introduced to gain competitive advantage.

2. Environmental:
   a. Complying with environmental regulations: through regulatory management (mitigating risks from regulation).
   b. Reducing environmental impacts: adopting closed loop energy mapping (through renewable energy source), CO2 neutral life cycle of the products, using pure materials with known and healthy properties.
   c. Improving resource efficiency: Resource efficiency can be achieved in products (use of renewable resources flows and the elimination of waste), in production (innovative sustainable production techniques, regeneration of energy in production, efficient use of machines on site management level) or in transport and logistic.
   d. Improving Supply Chain sustainability: by achieving organizational and supply chain resiliency (through environmental practices as recycling of wastes) or by resource management and reduced impact through the supply chain.
   e. Reducing Supply Chain: through an accurate selection along the supply chain.

3. Social:
   a. Enhancing reputation and brand value: Sustainability becomes a distinctive element of good corporate reputation and also a (green) marketing feature of the brand increasing customer loyalty. Reputation and brand value can be increased also through strategic partnerships with sustainability leaders and through the enhancement of sustainability performance to achieve good rating in sustainability indices and funds.
   Brand value can also lead to attract employees through sustainable value proposition, to higher employee motivation, to better customer service, to enhance the quality of activities, resources and partnerships.
   b. Reaching new markets & countries: Understanding different market needs for efficiency. Understanding how to change behaviors and drivers of mind-set change.
   c. Improving health & safety in workplace
   d. Developing innovative skills and knowledge: unfolding the full sustainability-potential of innovations enables modified or new VPs. Innovative products and services creating solutions to sustainability problems, improving customer retention. To allow for innovations to unfold may require new activities, resources and partnerships, higher innovation potential and expectations for profitable innovations leading to an increased shareholder value.

Author	Industrial Benefits												
	Economic					Environmental				Social			
	Reducing overall costs	Reducing business risks	Opening new revenue streams	Reducing product / process complexity	Improving competitive advantage	Complying with environmental regulations	Reducing environmental impacts	Improving resource efficiency	Improving supply chain sustainability	Enhancing reputation and brand value	Reaching new markets & countries	Improving health & safety in workplace	Developing innovative skills and knowledge
(Christmann, 2000)	x												
(Epstein, 1996)	x												
(Porter and van der Linde, 1995; Porter and Van Der Linde, 1995)	x												
(Schaltegger and Wagner, 2006)		x											
(Cohen and Winn, 2007)													x
(Pujari, 2006)													x
(Schaltegger and Wagner, 2011)													x
(Schaltegger et al., 2011)	x	x								x			x
(Park et al., 2010)	x		x			x			x				
(Jing and Jiang, 2013)			x				x	x		x			
(Roos, 2014)			x				x	x		x			
(McKinsey Global Institute, 2011)	x	x	x	x	x	x	x	x	x	x	x		
(Franco, 2017)				x			x	x	x				
(Sannö et al., 2014)				x	x		x	x			x		
(de Lange and Rodić, 2013)			x	x	x		x						
(Rizos et al., 2015)	x				x						x		
(Romero and Rossi, 2017)					x		x	x					
(Jones and Rubin, 2001)										x			
(Ehnert, 2009)										x			
(Revell et al., 2010)										x			
(Tecchio et al., 2017)							x	x					
(Bertoni, 2017)	x	x			x	x			x	x	x		

(Lindström, 2016)	x		x				x	x	x			x	x
(Velte and Steinhilper, 2016)				x									
(De los Rios and Charnley, 2017)								x					
(Ripanti et al., 2016)									x				
(Schischke et al., 2016)				x									
(Rashid et al., 2013)								x					
(Jawahir and Bradley, 2016)	x							x					
(Kane et al., 2017)	x							x					
(Lieder and Rashid, 2016)							x	x					
(Masi et al., 2017)	x	x	x				x	x		x			
Total	**12**	**5**	**7**	**6**	**6**	**3**	**11**	**14**	**6**	**9**	**4**	**1**	**5**

Table 3: CE-related industrial benefits from literature

Considering what is reported in **Table 3**, some information can be gathered about the current focus of CE-related Industrial benefits literature and existing gaps. Just numbering the amount of articles based on reference CE-related industrial benefits classes, it is possible to see that some types of industrial benefits are more frequently taken into account than others. For example, the most common industrial benefits described in literature when speaking about CE are represented by resource efficiency, costs and environmental impacts. Then, there are other industrial benefits. These are focused on brand reputation, revenue streams, product/process complexity, competitive advantage and supply chain. Finally, there are other CBMs not so commonly described in literature. These are focused on business risks, skills and knowledge, new markets, regulations and health and safety.

What is evident from the presented literature is that there is a big research gap in terms of new ideas on how to involve final users in circular economy. Just in very few cases the experts present innovative ideas and implement them in practice. In general terms, the social aspect related with CE adoption is rarely taken into account by the experts. Instead, the most common aspects considered by the literature are related with economics and environment. The FENIX project tries to fill in this research gap through the involvement of final users within CBMs. This last point represents one of the key elements for the final selection of the FENIX CBMs.

3.1. Identification of the FENIX industrial benefits

In order to gather information about the industrial benefits expected by FENIX partners from the adoption of circular economy practices, a set of face-to-face interviews have been done in the last two months. In addition, those partners not directly interviewed (SAT, UNIVAQ, BALANCE, CERTH, SINGULAR and GREEN) were periodically consulted via phone/web calls about the same issues discussed with the others. The interviews were not based on a pre-defined questionnaire, but exploited a set of open questions about both the current and future perspective of some of the FENIX partners, or FCIM, I3DU and MBN.

FCIM is a technological centre of the Polytechnic University of Catalonia focused on production technologies. FCIM contributes to the know-how related to engineering and technology management in a high-tech environment. Its institutional goal is to provide technological tools and support promoting synergies between the different parties (companies, universities, stakeholders and users). FCIM develops products and technological processes using a wide range of advanced manufacturing technologies and materials. Within FENIX, FCIM's role is devoted to prototype different products at its pilot plant using different additive manufacturing technologies, such as laser processing, fused deposition modelling, ink deposition or a hybridization of them. In addition, FCIM will study the influence of new manufacturing processes on CBMs. The adoption of circular economy within FCIM will allow to expand the source of composite materials (metals/non-metals) to be mixed within 3D printing filaments. These mixes could result from the integration of several metals (e.g. titanium, iron, copper, aluminium or nickel) with other materials like waxes, resins, glass fibres or plastics (e.g. PLA, ABS or Nylon). Their focus is either on filaments or final products. Reference markets could be: medical prothesis, aerospace components, artistic handmade products, industrial magnets, sport equipments.

I3DU is a startup specialized in 3D printing and 3D scanning processes. Its purpose is providing professional 3D printing and 3D scanning services to the market. Products and services offered by I3DU (and its online branch at 3DHUB), are 3D printing and scanning hardware and services, development of 3D printing materials (filaments as well as binders and powders) and development of custom 3D printing and 3D scanning solutions (both hardware and software), plus 3D Design and support/training services. I3DU also has in depth operational experience in working with and in helping to refine a system for taking orders automatically through localized points of sales and processing and 3D printing these orders centrally through a cloud based system. Within FENIX, I3DU's role is multiple. From one side, I3DU will develop 3D printed jewels, by exploiting its existing

expertise. From another side, I3DU knowledge on materials for 3D printing will be instrumental to develop new 3D printing filaments that will be tested and validated directly in I3DU facilities. The adoption of circular economy within I3DU will allow, like in FCIM, to expand the source of composite materials (metals/non-metals) to be mixed within 3D printing filaments. However, in this case the resulting 3D printing filaments will be different from the previous ones. From one side, the development of a new filament constituted by copper-based core and a layer in composite materials will be investigated. From another side, several alternatives will be investigated like: 1) the mix of metals with waxes, 2) the mix of different plastics (e.g. PLA or ABS) with glass fibres and 3) a liquid resin constituted by a mix of metals and glass fibres.
MBN is a nanostructured powder materials producer. Through a proprietary mechano-chemical synthesis process technology, MBN offers to the market innovative materials that can be treated using the conventional powder metallurgy and deposition processes such as Laser Sintering, Thermal Spraying and Sintering. Typical output of the process is constituted by agglomerated powders in the micron-size range constituted by aggregates of nanocrystals and nanoparticles obtained by High Energy Ball Milling of the elements in powder. The powder materials produced find application in a number of manufacturing chains as, conventional and fast sintering, laser sintering and coating deposition. Within FENIX, MBN's role is devoted to testing and validation activities on innovative green powders made starting from UNIVAQ's recovered materials. The adoption of circular economy within MBN will allow to develop "green" additive manufacturing powders to be exploited in several markets and sectors. These powders could also become an input material for both FCIM and I3DU 3D printing processes.

The overall summary about expected industrial benefits coming from the adoption of CE given by all of the FENIX partners is reported in **Table 4**. Just numbering the amount of preferences coming from the FENIX consortium is possible to specify (from another perspective than the literature) what are the expected benefits a generic company could obtain from the adoption of CE practices. What is relevant in this case is the high importance reached by social aspects like the development of innovative skills and knowledge within the company and the enhancement of brand reputation and value. This last point seems to be as much important as overall costs reduction and resource efficiency improvement. A second set of benefits is a mix of both economic and environmental expectations. Lot of attention is given to the reduction of the environmental impact. Then, reduction of business risks, improvement of competitive advantage and supply chain sustainability and provisioning share the same ranking. Opening new revenue streams and reducing supply chain complexity share the last place of this group. Finally, complying with environmental regulations, reaching new markets and countries, reducing product/process complexity and improving health and safety of workplaces seems to be out of scope for the FENIX partners.

Partner	Industrial Benefits													
	Economic					Environmental						Social		
	Reducing overall costs	Reducing business risks	Opening new revenue streams	Reducing product / process complexity	Improving competitive advantage	Complying with environmental regulations	Reducing environmental impacts	Improving resource efficiency	Improving supply chain sustainability & provisioning	Reducing supply chain complexity	Enhancing reputation and brand value	Reaching new markets & countries	Improving health & safety in workplace	Developing innovative skills and knowledge
SAT	x	x	x		x	x	x	x		x	x	x		x
POLIMI	x	x	x		x	x	x	x	x	x	x	x		x
UNIVAQ	x		x		x		x	x		x				x
FCIM	x							x	x		x			x
BALANCE		x					x		x		x			x
SINGULAR		x					x	x	x		x			x
GREEN	x	x	x		x	x	x	x		x	x	x		x
I3DU	x				x			x	x		x			x
MBN	x	x			x				x	x	x			
CERTH	x		x				x	x						x
Total	**8**	**6**	**5**	**0**	**6**	**3**	**7**	**8**	**6**	**5**	**8**	**3**	**0**	**9**

Table 4: CE-related industrial benefits selected by FENIX partners

3.2. Identification of the FENIX CBMs

The overall perspective about adoptable CBMs coming from the FENIX partners is reported in **Table 5**. Like well-evidenced in the next table, the final decision (based on majority judgement) was to focus on three different CBMs: 1) recycling, 2) result-oriented PSSs and 3) use-oriented PSSs.
In the first case, the final output of the FENIX's small-scaled circular economy could be either a full pilot plant or a specific product to be sold into the market. The full pilot plant will be able to either disassemble products, recover materials or manufacture 3D printed components/products. On the other hand, depending on the adopted additive manufacturing process, the specific product could be either a 3D printed jewel, a metal powder for additive manufacturing processes, or an innovative 3D printing filament.
In the second case – trying to follow an increasing involvement of both industrial and common people – the FENIX's small-scaled circular economy could function like a service company. This way, use-oriented PSSs could be adopted. All of the three labs constituting FENIX could act either together or independently like service providers focused on a particular stage of the process. This way, the POLIMI's lab could act as a provider of assembly/disassembly services for complex products; the UNIVAQ's lab could act as a provider of material recovery/refining services; finally, the FCIM, I3DU and MBN labs could act as providers of additive manufacturing services.
In the third case – to more efficiently involve people into the process – the FENIX's small-scaled circular economy could function like a Fablab. The final aim is sharing the whole process with final users. This way, the full potential offered by the FENIX project could be exploited also by private customers willing to have the chance to implement their ideas, by implementing a result-oriented PSS. Among the FENIX labs, the POLIMI's lab is currently the only one already able to adopt this kind of CBM.
In addition, given the high presence of both industry 4.0 and additive manufacturing technologies, the FENIX project could also give a practical demonstration about the adoption of "Exchange" CBMs.
The POLIMI's Industry 4.0 laboratory will be exploited within the FENIX project. This lab will constitute both the initial and final stage of the small-scaled circular economy represented within FENIX. This lab is already functioning like a demonstration plant for an automatic assembly of complex products. The intent of FENIX is to partially reconfigure it to make it able also to do disassembly procedures. Given the university context of POLIMI, the adoption of a Fablab-like CBM is expected to be more feasible than in other contexts.

The UNIVAQ's chemical laboratory will be exploited within the FENIX project. This lab will constitute the central stage of the small-scaled circular economy represented within FENIX. The lab: 1) will receive disassembled PCBs from POLIMI's lab, 2) will recover materials from them and 3) will send recovered materials to other partners (I3DU, MBN, FCIM) for their exploitation in additive manufacturing activities. The intent of FENIX is to partially reconfigure it to make it able to recover selected materials with specific features (e.g. particle's shape, dimension, purity level). Given the high specialization of the lab and the presence of patented processes, not all of the selected CBMs will be reproduced in this case.

The FCIM, I3DU and MBN's additive manufacturing laboratories will be exploited within the FENIX project. These labs will constitute either the semi-final and final stage of the small-scaled circular economy represented within FENIX, depending on the final type of product to be made. From one side, if the additive manufactured product is going to be a component of a more complex one, it will be sent to the POLIMI's lab for the final assembly. From the other side, if the additive manufactured product is going to be a final one, the process will stop. The intent of FENIX is to partially reconfigure these labs to make them able to produce specific products and/or components, like defined within the proposal. Also in this scenario, given the high specialization of the lab and the presence of patented processes, not all of the selected CBMs will be reproduced in this case.

Partner	Circular Business Models													
	Regenerate		Share					Optimize		Loop		Virtualize		Exchange
	Renewable energies	Bio- / Secondary materials	Co-ownership	Co-access	Use-oriented PSSs	Reuse	Repair	Industrial Symbiosis	Product-oriented PSSs	Refurbish / Remanufacture	Recycling	Result-oriented PSSs	De-materialize	New technologies
SAT											x			
POLIMI					x						x	x		x
UNIVAQ											x	x		
FCIM					x				x		x	x		x
BALANCE					x						x	x		
SINGULAR					x						x	x		
GREEN											x			
I3DU					x				x		x	x		x
MBN									x	x	x	x		x
CERTH					x						x	x		
Total	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**0**	**3**	**1**	**10**	**8**	**0**	**4**

Table 5: Circular Business Models selected by FENIX partners

4. INTEGRATION OF THE SCIENTIFIC AND INDUSTRIAL PERSPECTIVE

Once both the set of CBMs and the list of the most important industrial benefits to be exploited in the FENIX project were identified, the final stage was the integration of these two views in a common matrix. The following tables report how the FENIX CBMs are expected to satisfy industrial benefits from the point of view of all the FENIX partners.

4.1. Implementation of the FENIX assessment matrix

One of the most important elements to underline before the integration of CBMs and industrial benefits in the same matrix is the selection of the focus of the analysis. FENIX, from this side, is completely based on a multiple perspective, considering in parallel both a production plant and final product view.

Figure 9: The FENIX multiple perspective – production plant vs final products views

Starting with the production plant view (left side of **Figure 9**), it is possible to adopt like FENIX CBMs essentially three kinds of PSS-based business models. These CBMs are product-oriented, use-oriented and result-oriented ones. Firstly, a product-oriented BM could be adopted if the final aim of the future FENIX company will be the simple selling of the production plant (or some of its independent modules). Secondly, a use-oriented BM could be implemented if the final aim will be the selling of the access to the future FENIX plant (hypothesising that final users will have the right skills to exploit it). Finally, a result-oriented BM could be adopted if the final aim will be the selling of the several services (e.g. disassembly, materials recovery and additive manufacturing) related to those activities enabled by the FENIX plant. a summary of these CBMs is presented in the next **Figure 10**.

Figure 10: CBMs related with the FENIX production plant

Table 6 depicts the relation of selected CBMs with the expected industrial benefits perspective.

	FENIX “Exchange” Circular Business Models		
FENIX Industrial Benefits	**Product-oriented PSSs**	**Use-oriented PSSs**	**Result-oriented PSSs**
Reducing overall costs	U	U	U
Reducing business risks	P	P	U
Opening new revenue streams	-	P	P/U
Improving competitive advantage	P/U	P/U	P/U
Complying with environmental regulations	P/U	P/U	-
Reducing environmental impacts	P/U	P/U	P/U
Improving resource efficiency	P/U	P/U	P/U
Improving supply chain sustainability & provisioning	U	U	P
Reducing supply chain complexity	U	U	P
Enhancing reputation and brand value	P	U	U
Reaching new markets & countries	-	-	P
Developing innovative skills and knowledge	P/U	U	U

Table 6: The FENIX assessment matrix – FENIX production plant

Here, the previous CBMs were grouped under the definition “Exchange” CBMs because all of them exploit Key Enabling Technologies (KETs) instead of traditional production processes. This way, always considering the ReSOLVE framework, they can be classified under the same umbrella. Another element to mention is about the nomenclature present in this (and in all the followings) table. With the symbol “U” the FENIX partners identified those industrial benefits enabled by a specific CBM from the perspective of the final user (in this case, the one who will use the production plant). instead, with the symbol “P” the FENIX partners identified those industrial benefits enabled by a specific CBM from the perspective of the producer (in this case, of the production plant itself). The symbol "P/U" identifies those industrial benefits in common between producers and users. Finally, the symbol "-" indicates that neither producers nor users will get those industrial benefits.

Now, let's consider the final product view (right side of **Figure 9**). In this case, it is possible to adopt like FENIX CBMs just two out of three kinds of PSS-based business models. These CBMs are product-oriented and result-oriented ones. Firstly, a product-oriented BM could be adopted if the final aim of the future FENIX company will be the simple selling of a product (e.g. metal powders, 3D printed jewels, materials for additive manufacturing and 3D printing filaments). Finally, a result-oriented BM could be adopted if the final aim will be the selling of the several services related to those products enabled by the FENIX plant.

Within the FENIX project, three different pilots will be implemented. The first one is related with the production of green metal powders for additive manufacturing processes. Starting from electronic scraps (that could be brought to the plant by either private and industrial customers), final products will be metal powders. Like described before, FENIX could adopt either the perspective of selling metal powders or the powdering service (see **Figure 11**).

Figure 11: CBMs related with metal powders

Table 7 depicts the relation of selected CBMs with the expected industrial benefits perspective.

		FENIX "Exchange" Circular Business Models	
FENIX Industrial Benefits		Product-oriented PSSs	Result-oriented PSSs
	Reducing overall costs	P/U	P/U
	Reducing business risks	U	U
	Opening new revenue streams	-	-
	Improving competitive advantage	P/U	P/U
	Complying with environmental regulations	-	-
	Reducing environmental impacts	-	-
	Improving resource efficiency	-	-
	Improving supply chain sustainability & provisioning	P	P
	Reducing supply chain complexity	P	P
	Enhancing reputation and brand value	U	U
	Reaching new markets & countries	-	-
	Developing innovative skills and knowledge	-	-

Table 7: The FENIX assessment matrix – metal powders

Here, in red there are those industrial benefits expected by the FENIX partner (MBN) who will be involved directly in the implementation of this specific pilot. Black industrial benefits were identified like non-fundamental ones.

The second one is related with the production of 3D printed jewels from green precious metals. Starting from electronic scraps (that could be brought to the plant by either private and industrial customers), final products will be 3D printed jewels. Like described before, FENIX could adopt either the perspective of selling jewels or the 3D printing service (see **Figure 12**).

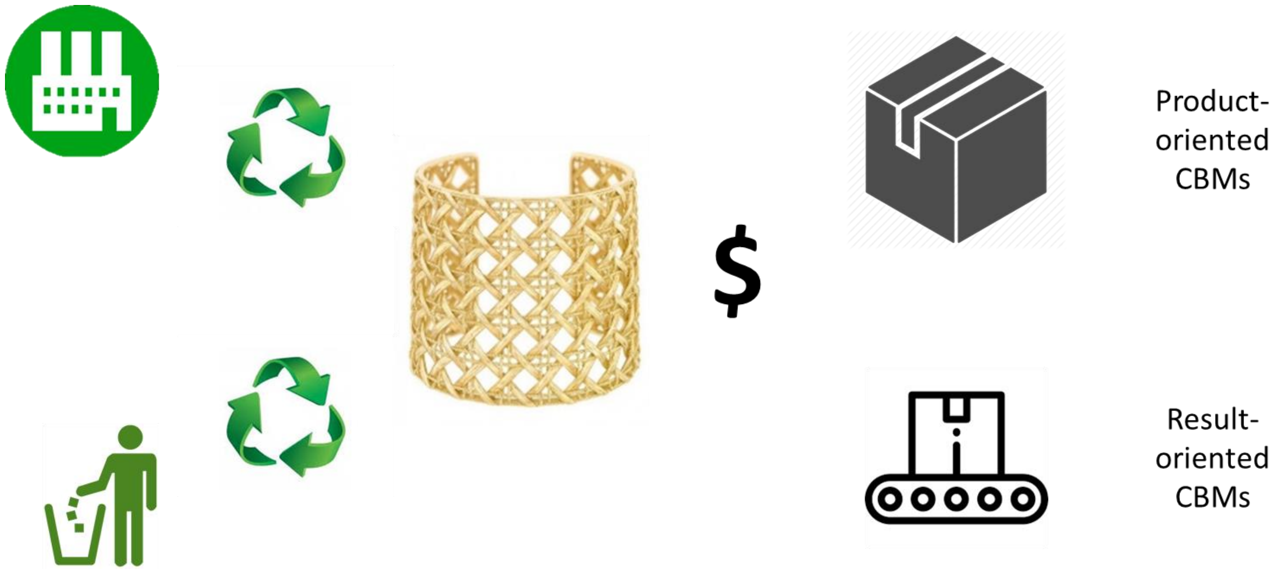

Figure 12: CBMs related with 3D printed jewels

Table 8 depicts the relation of selected CBMs with the expected industrial benefits perspective.

		FENIX "Exchange" Circular Business Models	
FENIX Industrial Benefits		Product-oriented PSSs	Result-oriented PSSs
	Reducing overall costs	P	P
	Reducing business risks	-	-
	Opening new revenue streams	-	-
	Reducing product/process complexity	P	P
	Improving competitive advantage	P	P
	Complying with environmental regulations	-	-
	Reducing environmental impacts	-	-
	Improving resource efficiency	P	P
	Improving supply chain sustainability & provisioning	P	P
	Reducing supply chain complexity	-	-
	Enhancing reputation and brand value	P	P/U
	Reaching new markets & countries	P	P
	Reaching new markets & countries	P	P
	Developing innovative skills and knowledge	P	P

Table 8: The FENIX assessment matrix – 3D printed jewels

Here, in red there are those industrial benefits expected by the FENIX partner (I3DU) who will be involved directly in the implementation of this specific pilot. Furthermore, in yellow there are those industrial benefits expected by great part of the FENIX partners, but not from I3DU. Finally, black industrial benefits were identified like non-fundamental ones.

The third one is related with the production of either Additive Manufacturing (AM) materials or 3D printing filaments from wasted materials. Starting from electronic scraps (that could be brought to the plant by either private and industrial customers), final products will be the previous two types of products. Like described before, FENIX could adopt either the perspective of these products or AM services (see **Figure 13**).

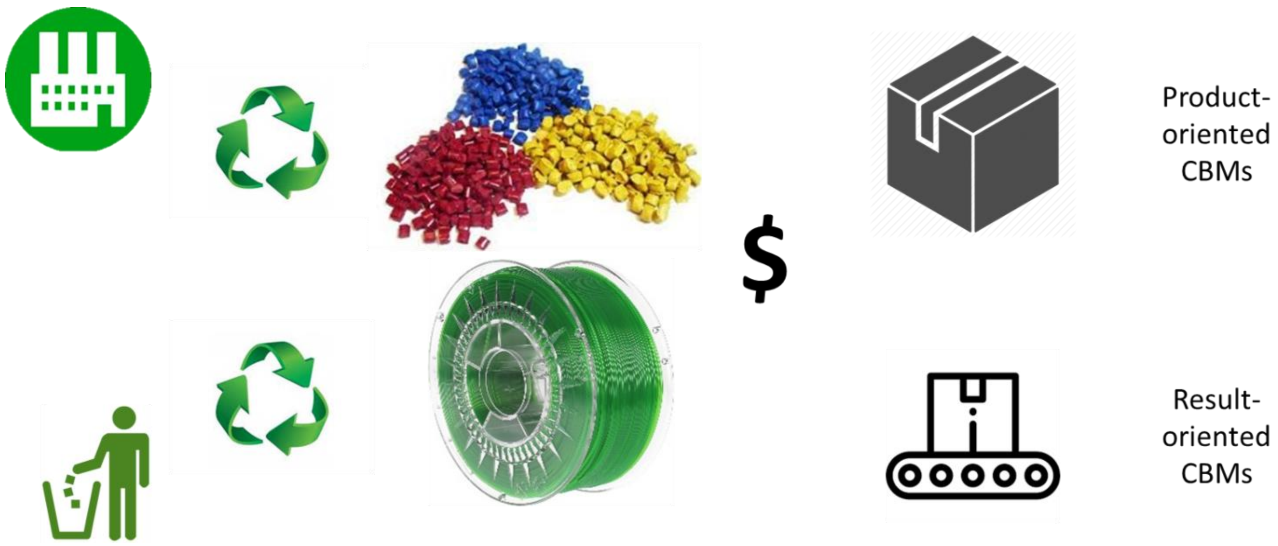

Figure 13: CBMs related with AM materials & 3D printing filaments

Table 9 depicts the relation of selected CBMs with the expected industrial benefits perspective.

		FENIX "Exchange" Circular Business Models	
		Product-oriented PSSs	Result-oriented PSSs
FENIX Industrial Benefits	Reducing overall costs	P/U	P/U
	Reducing business risks	-	-
	Opening new revenue streams	-	-
	Improving competitive advantage	P/U	P/U
	Complying with environmental regulations	-	-
	Reducing environmental impacts	-	-
	Improving resource efficiency	P/U	P/U
	Improving supply chain sustainability & provisioning	P/U	P/U
	Reducing supply chain complexity	-	-
	Enhancing reputation and brand value	U	U
	Reaching new markets & countries	-	-
	Developing innovative skills and knowledge	P/U	P/U

Table 9: The FENIX assessment matrix – AM materials & 3D printing filaments

Here, in red there are those industrial benefits expected by the FENIX partners (FCIM and I3DU) who will be involved directly in the implementation of this specific pilot. Finally, black industrial benefits were identified like non-fundamental ones.

What is evident from all of these tables is that there is not a CBM offering better chances to fill in great part of the expected industrial benefits. Instead, use-oriented and result-oriented PSSs will allow to better cope with social aspects related with CE.

5. CONCLUSIONS

Deliverable 1.1 identified three Circular Business Models (CBMs) to be adopted within the FENIX project. These CBMs were identified in product-oriented, use-oriented and result-oriented PSSs. For their identification, a multi-perspective procedure has been adopted. First of all, a state of the art analysis allowed to define the most common types of CBMs and their classification methods. Secondly, a set of dedicated interviews with all the FENIX partners allowed the definition of the most important industrial benefits expected from the adoption of circular practices. Together, the integration of both the scientific and industrial perspective allowed the identification of the most suitable CBMs to consider within the FENIX project, distinguishing among CBMs related to the pilot plant itself and CBMs related with specific products coming from the pilot plant. The intent of Deliverable 1.2 is the circularity assessment of these CBMs.

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