This paper was presented at The ISPIM Innovation Conference – Innovation, The Name of The Game, Stockholm, Sweden on 17-20 June 2018. The publication is available to ISPIM members at www.ispim.org.

21st Century Innovation: What's the name of the new game?

Allen T Alexander*

University of Exeter in Cornwall, Penryn Campus,
Falmouth, TR10 9FE, United Kingdom.
E-mail: A.T.Alexander@exeter.ac.uk

Peter Hopkinson

University of Exeter in Cornwall, Penryn Campus,
Falmouth, TR10 9FE, United Kingdom.
Email: P.Hopkinson@exeter.ac.uk

Jo Miller

Ellen MacArthur Foundation, The Sail Loft, 42 Medina Road, Cowes,
Isle of Wight, PO31 7BX, United Kingdom
Email: Jo.Miller@ellenmacarthurfoundation.org

Michele Miller

University of Exeter in Cornwall, Penryn Campus,
Falmouth, TR10 9FE, United Kingdom.
Email: M.M.Miller@exeter.ac.uk

* Corresponding author

Abstract:

The Circular Economy is a relatively immature research landscape, particularly when considered from an Innovation perspective. However it is gaining momentum and according to critics offers a solution to many of the issues currently being experienced around the world, in terms of resource shortages and the energy, food, water nexus. This study attempts to explore examples of products and services, collected by the Ellen MacArthur Foundation, to begin to understand which size of companies are developing them, what types of innovations they represent and how they might diffuse to scale. The contribution of this paper is to introduce, define and raise awareness of circular innovations whilst beginning to articulate how analysis of CE products and service might be undertaken by further studies, with the aim of informing companies and policy-makers accordingly.

Keywords: Circular Economy; Innovation; Diffusion; Adoption; Circular Innovation.

1 Introduction

In recent years there have been a number of surprises in the political and economic regimes of the western economies, where established trends in economic growth have been unseated by surprise electoral and political decisions in the UK, in Europe and in the US, bringing about fluctuation and turmoil to many established markets. These issues follow a decade of austerity in certain economies attempting to recover from the world-wide financial crisis of 2008.

Commentators have suggested the drivers for these surprises include social unrest and societal dissatisfaction with the status-quo (Pauli, 2013). We are however more well informed too as new digital and real-time communication systems have enabled news and opinion to percolate out to the voting masses more than ever before, some suggest "regardless of their factual content", but what is fuelling this dissatisfaction?

Obviously there are many inter-connected factors but one of particular note is the growing realisation at a policy-level and at a citizen-level that our current approach to production and consumption is not only unsustainable, but the bi-products and waste-products of this process are harming our planet's natural resources and thus our own economies beyond repair (Steffen et al., 2015). So what is the solution and how might new ways of innovating offer the world's economies more widespread, inclusive and beneficial outcomes?

The Current Issue

Current production systems rely on the extraction of raw materials; of processing; of manufacturing and distribution, with the aim of offering consumers product and service utility whilst affording businesses and shareholders with maximal economic returns. But this linear process of 'take' and 'make' has led to huge problems with waste, and increasing issues around waste reduction being realised every year (Webster, 2017). It has also led to the acknowledgement that our planets ecosystem services are being damaged and numerous resources are becoming scarcer. Modern societies that rely on the consumption of high levels of power, water and food can no longer assume security of supply to meet these demands (Ghisellini et al., 2016). Innovations in health and social care have also compounded this problem with populations growing and living longer, thus increasing demand. But what solutions exist to these systems level issues?

Since the 1970 there has been a slowly evolving argument, taking its emphasis from our planets natural economic cycles of regeneration and principles of zero waste, which suggests a "revolution" is required to arrest these trends – a revolution toward a more Circular Economy (Stahel, 2016).

Synthesising a range of definitions and attempting to create a simple definition the idea of a 'Circular Economy' brings forward and builds on many of the components of previous schools of thought, such as "cradle to cradle design thinking", performance economy and natural capitalism and thus proposes a systems level innovation framework for change. But will it be different in terms of corporate adoption? Is the mode of diffusion different, when viewed through an innovation lens and if so how? Have we reached a point where rather than "doing the right thing", there is now an imperative to do "what is now essential"?

The aim of this submission is to map a sample of examples of recent circular products and services against well-established models from the innovation literature, to try to identify some of their key characteristics and explore the potential for these new innovations to diffuse to scale. Whilst these examples may represent the first steps toward circular economic maturity (Murray et al., 2017), the paper aims to

inform the discussions about how wider CE, systems-level change might be achieved and whether this should be accelerated by top-down (policy-level), citizen-driven (societal and community-driven) or any other combination of driving force accordingly.

This paper presents a brief overview of recent contributions to the definition of circular economy and describes the specific framework and principles that underpin the specific sample of cases that forms the main analysis. We then assemble a number of simple heuristics, from existing and popular innovation frameworks and analysis within the innovation literature. These frameworks are then applied to a case library of 90 CE examples, collected and collated by the Ellen MacArthur Foundation (EMF), under their definitions of circularity, over the past 3 years. Each case is interpreted and then allocated into the respective frameworks, to illustrate the range and forms of CE innovations. The paper closes with a discussion of whether these frameworks are useful, whether better analytics are required and how these might be developed with a view to better understanding the CE phenomenon. The closes with suggestions for further work to bring forward and define the concept of **Circular Innovation –** the name for a new game in the 21st Century.

2 Literature focussed on the Circular Economy and Innovation

Since the 1970 there has been a slowly evolving argument, taking its emphasis from our planets natural economic cycles of regeneration and principles of zero waste, which suggests a new, systems-level model is required to arrest these trends – a move toward a more Circular Economy (Stahel, 2016). There have been many claims for the origin of the term circular economy, with early references in the work of Boulding (1966). The enduring appeal of the term over this 50 years has produced multiple definitions and exists in a range of different incarnations across different contexts (Geissdoerfer et al., 2017). A short summary of some of the various definitions is shown in table 1.

Table 1 – Definitions of the Circular Economy

Authors	The Circular Economy is …
De Jesus & Mendonça (2018)	"a multidimensional, dynamic, integrative approach, promoting a reformed socio-technical template for carrying out economic development, in an environmentally sustainable way, by re-matching, re-balancing and re-wiring industrial processes and consumption habits into a new usage-production closed-loop system".
Korhonen et al. (2018)	"an economy constructed from societal production-consumption systems that maximizes the service produced from the linear nature-society-nature material and energy throughput flow… using cyclical materials flows, renewable energy sources and cascading 1-type energy flows" ***and*** "CE promotes high value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers and other societal actors in sustainable development work".
Franco (2017)	"a purposefully designed, interconnected system where

	materials flow in a closed-loop manner in order to advance sustainability".
Geissdoerfer et al. (2017)	"a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling".
Murray et al. (2017)	"an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being"
den Hollander et al. (2017)	where "the economic and environmental value of materials is preserved for as long as possible by keeping them in the economic system, either by lengthening the life of the products formed from them or by looping them back in the system to be reused. The notion of waste no longer exists in a CE, because products and materials are, in principle, reused and cycled indefinitely".
Sacchi Homrich et al. (2017)	"a strategy that emerges to oppose the traditional open-ended system, aiming to face the challenge of resource scarcity and waste disposal in a win-win approach with economic and value perspective".
Prieto-Sandoval et al. (2017)	"an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions and governments) levels. Attaining this circular model requires cyclical and regenerative environmental innovations in the way society legislates, produces and consumes".
Kirchherr et al. (2017)	"an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."
Haas et al. (2015)	"a simple, but convincing, strategy, which aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows".
Webster (2013)	"increasingly built on renewables, and the endless flow of energy from the sun (energy in surplus), a circular economy is one which transforms materials into useful goods and services (waste ↔ food). It builds capital and maintains it."

Source: As cited

As an emerging research discipline or a concept for commercial adoption, CE is thought of as an 'umbrella concept' (Blomsma and Brennan, 2017) often focussed on waste and resource management, increased resource productivity and new business models. Adoption of CE in terms of production and operations is extensive with various ways of describing or classifying the value creation and capture from circular economy value chains (Bocken et al., 2017, Geissdoerfer et al., 2017). In this context there is a broad consensus that current production systems rely on the extraction of raw materials; of processing; of manufacturing and distribution, with the aim of offering consumers product and service utility whilst affording businesses and shareholders with maximal economic returns. But this linear process of 'take' and 'make' has led to huge problems with waste, with more and more issues around waste reduction being realised every year (Webster, 2017). It has also led to the acknowledgement that our planets natural resources are being damaged and our mineral resources are becoming scarcer and/or less secure. Modern societies that rely on the consumption of huge quantities of power, water and food can no longer assume there will be enough (Ghisellini et al., 2016). Innovations in health and social care have also compounded this problem with populations growing and living longer, thus increasing demand. But what solutions exist to these systems level issues?

According to Webster (2017), the roots of what we currently term the Circular Economy come from a range of intellectual disciplines (Environmental Sustainability, Industrial Ecology and Ecological Economics are three fields currently acknowledged most frequently) and theories that underpin the activity are Resource-based Theory, Systems Theory, Institutional Theory and Stakeholder Theory. However our definition above aims to revise the linear take-make-dispose economy models we are currently locked into and bring forward one that is "regenerative by design" (EMF, 2012 p.4) - See Figure 1.

One of the most enduring images associated with the CE is entitled the butterfly diagram (See Figure 2) which has been through a number of iterations but still offers a good starting point for visualizing production and business operational practices.

The systems framework is underpinned by three key principles shown and this version of CE draws from a number of schools of thoughts including cradle to cradle design thinking, performance economy, natural capitalism and biomimicry. The framework is operationalized through a set of concepts, building blocks and key value loops. Key concepts include the need to design for two material cycles, referred to as technical and biological. At its simplest the creation, capture and circulation of value typically demands that products and services are designed at the outset for circulation and cascading 'systems' in order to recover embodied materials and energy and create revenue and cash flows. This requires the co-ordination, creation and management of reverse networks and the adoption of business models to incentivize consumers and end-users to support return and re-use. Such activities are enhanced by digital technology such as re-commerce platforms, and a wider set of enabling system conditions such as policy and regulatory initiatives, cross value-chain collaborations and new forms of financing.

In practical terms technical materials such as metals, are durable and thus can, with effective design, business model and processing conserve the product and component integrity instead of discarding it at end of first use life. Value is therefore extracted over a number of usage cycles. In the biological sphere, materials that are used are not reused as their original properties, can cascade through bio-refining, anaerobic digester or secondary use phases. For example cotton, made into garments can be taken back, shredded and made into subsequent insulation for buildings.

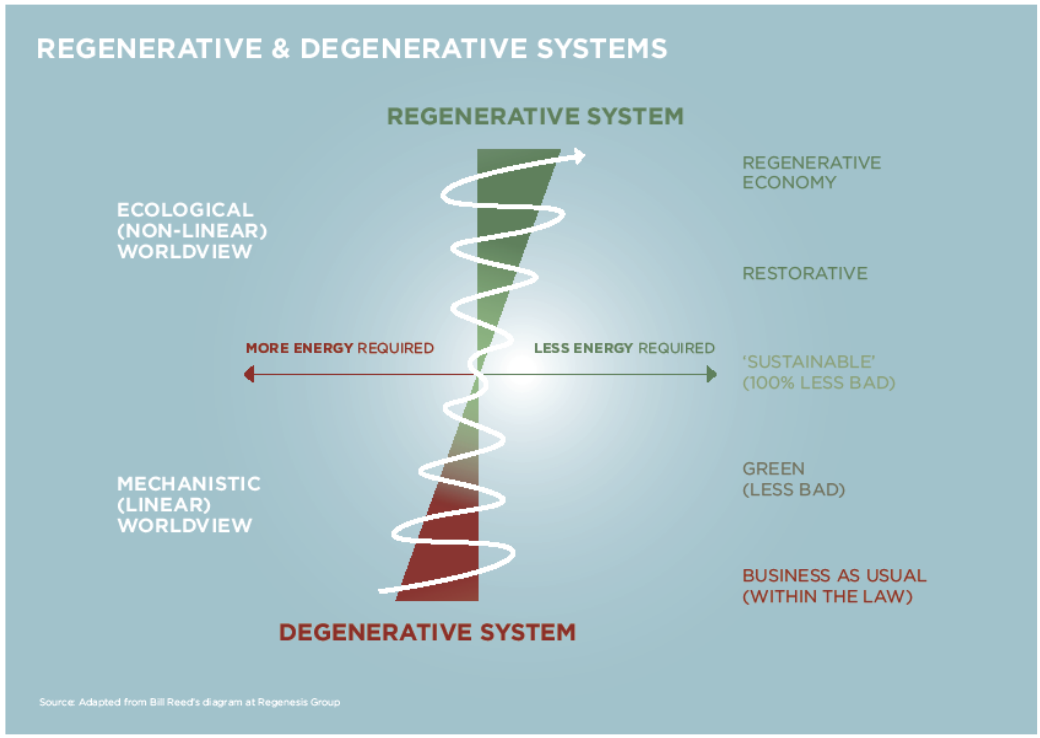

Figure 1 – Regenerative & Degenerative Systems

In all cases, the preservation of value is highly dependent on avoiding contamination, hazardous or toxic materials and additives which inhibit subsequent re-circulation. This goes hand-in-hand with the assumption that energy is provided via renewable sources and thus reducing fossil fuel consumption and reducing subsequent emissions accordingly.

Innovation and diffusion

The Innovation research domain is approaching maturity and with it comes extensive research exploring many of the antecedents, barriers, processes and outcomes of introducing new products or services. As a component of this, the study of the diffusion of innovation brings forward many frameworks attempting to explore the phenomenon of how and why innovations take hold and move to scale.

When considering adoption at scale, Tidd and Bessant (2005) bring forward an idea that products and services are often conceived as unique and market-level offerings, firstly taking a hold in a select market environment. Other innovations may attempt to take hold in a more national or regional or even a systems-level setting. Likewise they also suggest innovations can be of different types, in terms of their newness or uniqueness. They offer a simple frameworks, that presents product or component-level offerings in contrast to systems-level offerings and the compare this to incremental (do better) or radical (do different) innovations. Each segment of the model reflects a variety of risk and uncertainty, with systems level, radical innovation being the least well understood and therefore offering the highest levels of risk, when compared to incremental, product level offerings.

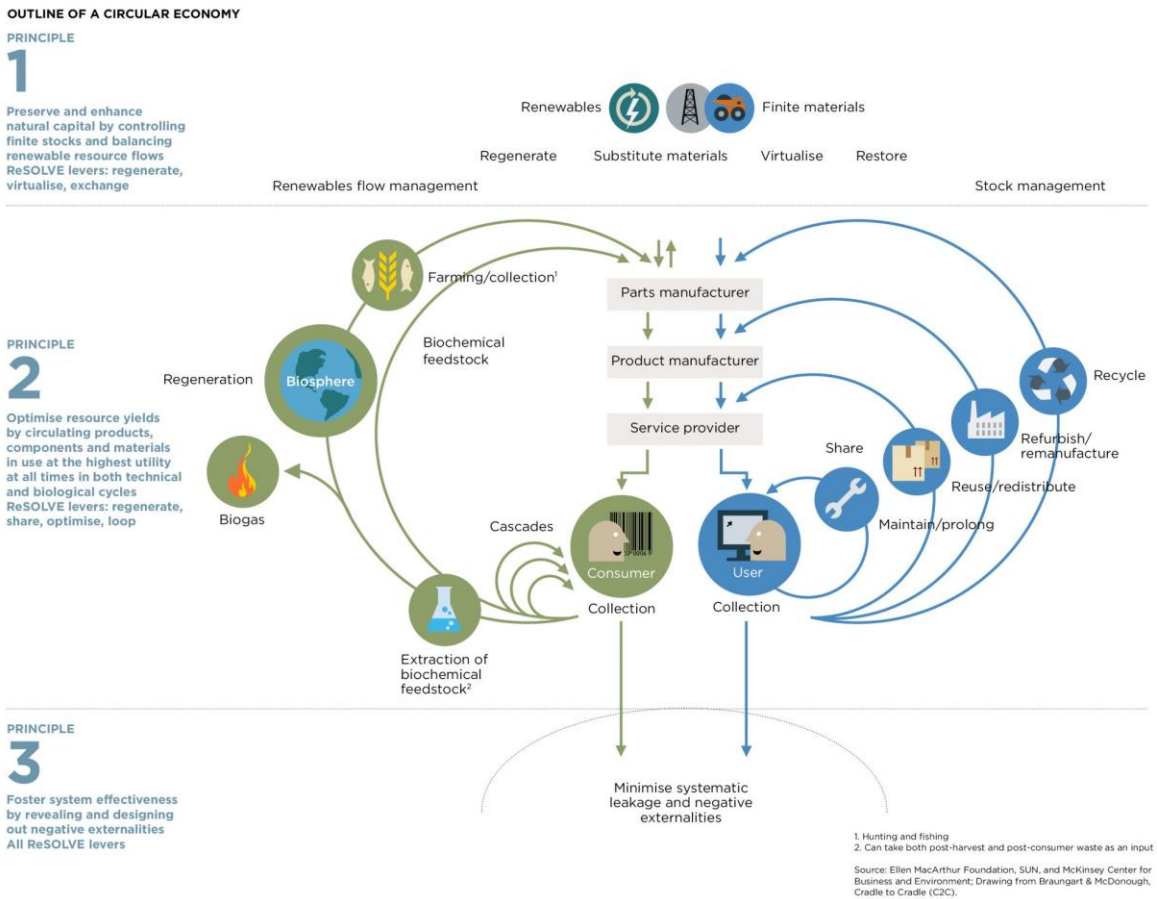

Figure 2 – The Butterfly Diagram (EMF, 2012)

By comparing this level of risk and uncertainty with models of market development, similarities can be seen from the work on market types and market development strategies (Ulwick, 2005). Thus we can identify similarities in terms of core markets (where the current product offerings are situated), adjacent markets where current offerings could be extended (and where the current markets share similarities with the core market) and breakthrough markets, where little is known of the market and where new products or service would be breaking through.

Overlaying the model of innovation diffusion (Tidd & Bessant, 2005) and the model of market penetration of Ulwick (2005) along the common axis of risk and uncertainty, Figure 4 offers a combination of the two approaches as an analytical framework with which to review new innovations, in terms of their market, their focus of impact and their relative type of innovation.

If we now have groundings for both the CE and innovation diffusion from the literature and we are aiming to explore the phenomenon of CE diffusion, we are able to construct some indicative and emerging research questions:

- Are new CE offerings merely new versions of sustainable or responsible innovations and if not how are the offerings positioned on the spectrum between CE product-level offerings and more CE systems-level offerings?
- How do these examples relate to our understanding of incremental and radical innovations?

3 Methodology

We have selected a cohort of case studies, as examples of business CE innovation, as the basis for exploring potential avenues for diffusion and scale-up. Our cases are selected from a data-base of 130 case studies and case-based examples of circular products and services collected and collated by the EMF. Having removed cases where the information is too limited to inform our analysis, we have a total of 90 cases shown in Annex 1. These cases are a random sample and hence we do not seek to generalise the findings. Rather they illustrate the wide range of innovations that fall under the CE umbrella, based on the framework and principles defined by the EMF.

4 Indications from the Case Studies and Framework

The cases provided by the EMF fall across a range of categories and were not originally selected against specific criteria or a systematic sampling procedure. They provide however an illustrative sample of cases that highlight aspects of circularity and useful units of analysis, although they as such make generalisation difficult. For example many of the cases are technical examples of circularity, some are biological examples. Likewise some of the examples look at the design of circular products and services, some of business model innovation focussing on circular principles whilst others are examples of remanufacturing or reuse. Examples of services offered to improve circularity principles at a municipal or societal level are amongst those that were removed from the original sample of 130. In populating the framework shown in Figure 4, a number of interpretations and assumptions were made to attempt to identify the relative positioning of the innovations.

Step 1 – Beginning to categorise the companies offering CE products / services.

Each of the 90 case studies are related to a company of some type, whether this be a Start-up, Micro-enterprise, Small, Medium or Large enterprise[1]. In terms of the large companies, when considering the reach of a new product or service, the operating domain of the large company becomes important. Therefore each of the case has been added to the following spectrum, shown in Table 2, with the cases thus categorised in Annex 1.

This led us to categorise 14 of the 90 cases as Start-up Enterprises, 9 as Micro Enterprises and a further 10 as Small Enterprises. 12 were Medium-sized Enterprises and 45 Large Enterprises, of which 14 had a national footprint and 31 a multi-national footprint. A simple representation of the distributions is shown in figure 3.

Step 2 – Distributing the case into the diffusion framework

Firstly the degree of incremental/radicalness was assessed. This was achieved in terms of whether the product or service was previously part of the company portfolio (incremental), whether it was new to the company or whether it was new to the world (radical) (Tidd and Bessant, 2015). Secondly the product or service was appraised to establish if it was impacting at a component level, a sub-system (such as national or sectoral) or systems level (Tidd and Bessant, 2009).

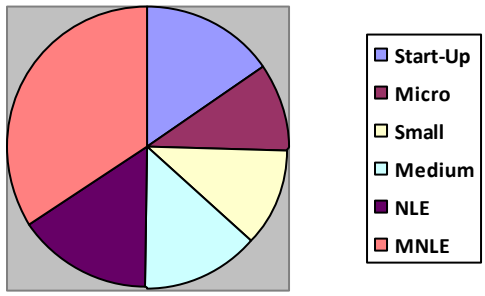

Figure 3 – Distribution of CE Product/Services by Firm Size

This led us to categorise 46 products or services as being largely component level activities, with a small handful creating an impact on a national or sectoral level, and that fitted into a definition that was largely incremental (do better). For example the design of platform-based electronic products for remanufacture in existing products offered to existing markets. This subsequently represented a relatively low level of risk and likewise reflected a conservative strategy in terms of new market penetration. In terms of companies undertaking this activity, there was a distinct bias to large and multi-national companies within this grouping, partially explained by the large number of such companies in the EMF membership but also indicating the early stages of CE adoption and diffusion are likely to fall into the low risk, first steps category.

[1] Micro, Small, Medium and Large categorisations follow the EU standard classification guidelines - http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en

Table 2 – Firm Size for CE categorisation

Start-Up	Micro Enterprise	Small Enterprise	Medium Enterprises	National Large Enterprise	Multi-national Large Enterprise
New Firm (created explicitly to launch new Product/Service)	Existing Firm with 0-10 staff equivalent	Existing Firm with 10 – 50 staff	Existing Firm with between 50 - 250 staff	Existing Firm with more than 250 staff	Existing Firm with Multi-national footprint and more than 250 staff

In terms of a further grouping of 32 products or service these could be indicated as more orientated toward component level activities but moving toward greater risk in terms of more radical products, new to the company and in some cases new to world. These were more often found amongst early stage organisations and entrepreneurs, for example where a start-up organisation is bringing forward a new leather material to replace widely-used leather in the textile industry, but grown from micro-organisms and bacteria.

In terms of establishing products and services that were both new to company and operating across a distinct sub-system level, we saw only a small number (9) fitting into this category, with an equal share of SME, national large and multi-national companies, but no start-ups (An example of this was in the automotive sector where remanufacturing opportunities has led to the development of new proprietary products with greater cradle-to-cradle potential). Finally the smallest grouping were those that might be classified as radical (new to the world) offerings that were trying to establish themselves as systems-level activities and this group were entirely reliant on start-ups for their activity (such as a new of bioengineering technology that brings waste materials and catalyses them to create new versions of existing chemicals for use in large scale production systems). An indication of this grouping is shown in Figure 4.

5 Discussion

In attempting to classify the cases against two simple heuristics (the type of company developing the product or service – step 1, and the diffusion of the product or service –step 2) the following can be observed.

Of the 90 cases, 50% of the developments of CE products or services were originating from large and multinational companies. The remaining 50% were approximately equally shared across the remaining categories. According to Laforet (2008) there is an expectation that different organisational size will affect their propensity to develop new products and services, but there is no simple correlation across other studies from other regions (McAdam et al., 2004, Wan et al., 2005, Barney, 1991).

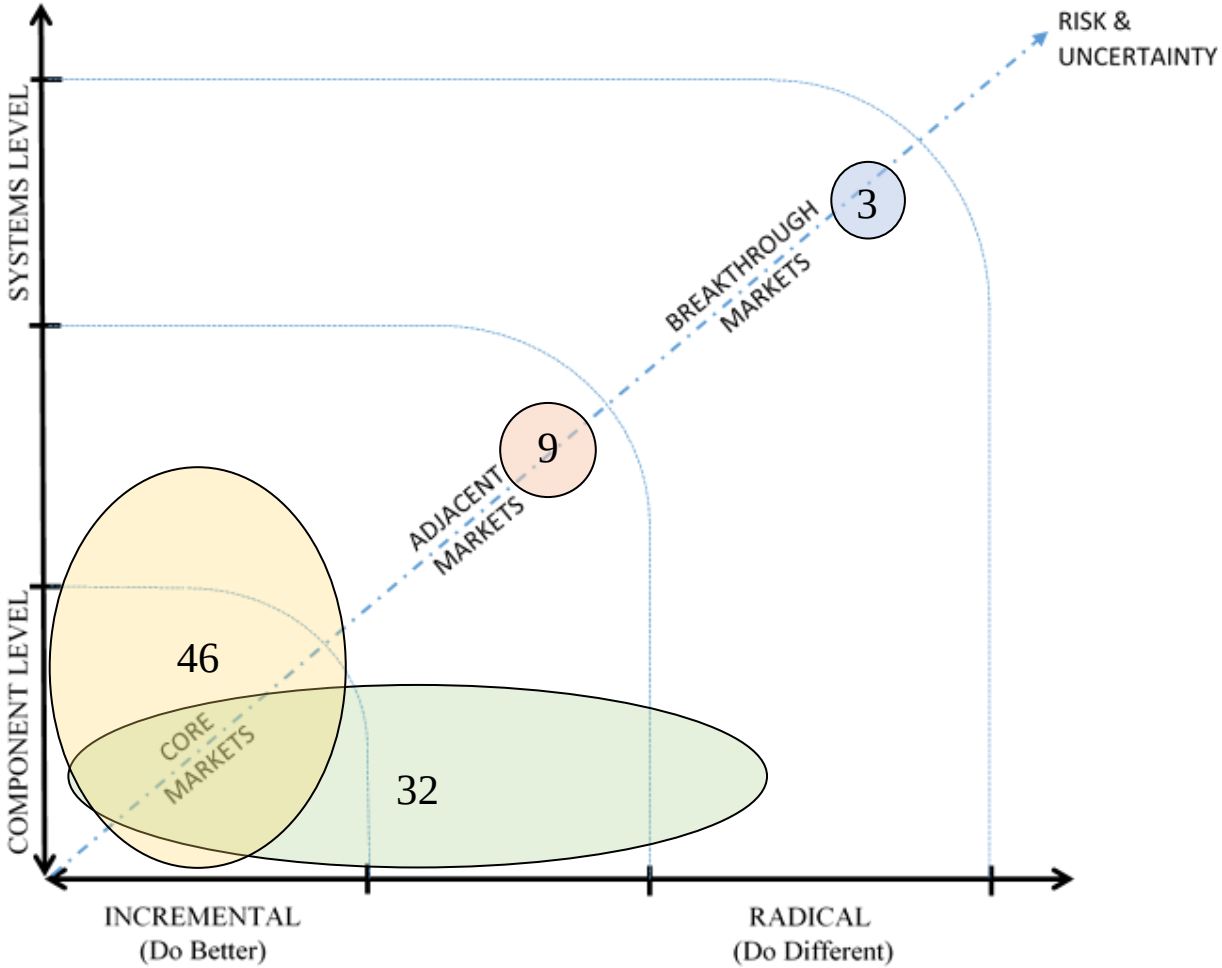

Figure 4 – Zones of Innovation Diffusion in the CE

As such there is no expectation for large companies to be more innovative than small companies; although there are many factors presented in the innovation literature that attempt to create this argument. For example, Tidd & Bessant (2015) argue that small firms can be as innovative as large companies if they link with other companies and exercise open innovation (Chesbrough, 2013), whereas Brunswicker and vanHaverbeke suggest the 'liability of smallness' can hamstring small companies in being innovative (2011). What each of the authors agree on however is that the capability to be innovative is a learned capability and as such can be developed within an organisation. This leads us to identify, in the CE context, that there is likely to be a similar construct to Innovation Management Capability (Adams et al., 2011) that will enable organisations to understand the way in which they can begin to develop "Circular Innovations".

What is particularly interesting however is the reliance on start-up organisations to attempt to bring forward products and services that present both 'new to the world' innovations that aim to represent the CE at a systems-level. This is surprising as in terms of achieving market penetration there is a definite correlation between firm size [and more importantly firm size and the territories that they are represented in – i.e. MNEs] (Brainard, 1993, Rugman and Verbeke, 2004). Likewise the tolerance to risk, required to deliver both radical innovation into breakthrough markets is also likely to suggest that a company might benefit from being resilient and buoyant in their current markets, before taking on such a task. That said however there is, within the extensive literature on entrepreneurship, confirmation that breakthrough innovation as well as disruptive innovations are often left to entrepreneurial insight to identify, whilst the incumbents miss the opportunities (Hargadon, 2003, Bessant and Tidd, 2011).

In terms of the degree of radicalness of the innovations, there are no surprises that the majority of the categorisations are both incremental and component-level offerings. These are most likely to create modest rewards for their companies but are also least likely to fail in their current markets. In terms of a company's response to a new type of product or service it is "normal" (Rothwell, 1992) to consider a new product to their existing market and to capitalise on the configurability of their current product offerings to offer an suitable incremental offering (Christensen, 2013, Cooper and Kleinschmidt, 1987) – it would be suggested that this makes good business sense particularly when developing more complex products that are required to focus on the Circular Economy.

In terms of the adequacy of the heuristics used to ground the above discussion points there are distinct weaknesses and areas that require more careful exploration. The granularity of the evaluation is not adequate enough to replicate any exact positioning, is entirely lacking a temporal dimension and also lacks any considered primary data collection relating to the case studies. Care must be taken to appreciate the exploratory nature of the discussion points above and also the criteria used by the case studies, which are entirely aimed at being illustrations of the products and services that fit within the definition of circular economy developments.

Similarly, some of the models put forward by EMF as figure 1 and 2 are not entirely revolutionary, and remanufacturing and asset reuse have long attracted both research and practitioners. The diffusion and adoption of these models has been studied in many ways, often examining factors inhibiting their scale up. There have been many reasons cited for this lack of traction, including branding, customer acceptance, failure to achieve an effective pricing strategy, issues with take-back and tooling requirements for remaking etc. etc. (Hatcher et al., 2012). The past 5 years however has started to see a significant shift in the market in certain industry sectors – remanufacturing for example growing at a faster rate in the US than manufacturing.

What has attracted policymakers and early adopters to the work of the EMF is the combination of the careful articulation of the resource-based economic arguments, combined with the economic and societal "perfect storm" noted above. As a result significant numbers of leading companies are now showing interest in the extension and expansion of circular practices, leading to the question of what new opportunities and challenges CE raises for such companies in terms of competitive business advantage and resultant requirements for supply chain redesign and indicator development, over and above pre-existing closed loop production practices. The examples in this paper illustrate some of the products or services that are being offered, under the umbrella of the CE, which we believe are fast becoming distinctive Circular Innovation practices.

Toward a more systematic approach to categorise the case studies

Whilst attempting to categorise the case studies it became evident that a wider appreciation of the ways in which the product or services fit with the context of the circular economy may be more appropriate to explore the cases and aid in the development of more granular criteria with which to understand the circular nature of the innovations.

Firstly it may be more appropriate to adopt a simple starting point that differentiates between the focal point of the innovation; design, business model, reverse network management, technical material innovations vs. biological innovations, systems and the role of digitally-enabled technologies. This would enable a revised set of evaluation criteria to be developed that note the variety of options present in the technical sphere when compared to those in the biological sphere.

Secondly the component sources of activity could be considered alongside the relative production cycles and recycles, enabling a better understanding of the nature of the innovation. For example does the innovation relate to renewable energy sources, does it include short cycles of supply chain procurement, is it suitable for remanufacture, refurbishment of recycling or does it degrade providing sources of biological feedstock etc. etc.

Finally the circular innovations could be categorised to establish is they are regenerative, restorative, sustainable and resource efficient as well as exploring their relative degrees of innovativeness and their diffusion and target markets. This would provide a far broader and more inclusive definition of 'Circular Innovations'.

6 Conclusions

From our work within this paper there are several basic conclusions that can be drawn, set against the limitations that this work is fundamentally theory-building and as such some of the simplifications and assumptions made in the classifications are not robust enough to rebut arguments of interpretive bias.

Firstly we can see from the wealth of new examples of CE products and services that the CE principles are gaining momentum and that new products and services are coming online that engender the fundamental arguments and fit within the revised and reworked definitions of the CE. We suggest that these could be referred to as Circular Innovations.

Secondly, by considering the locations across the world that are beginning to develop circular innovations, they are not solely limited to one continent, or taken from only the developed economies, for example. Likewise the spread of innovation across the spectrum of company sizes suggests that circular innovation is not the bastion of only the large or multi-national companies, even if these are the examples most often cited in the existing research and policy literature. What is important

therefore is to take forward examples of case studies from across the spectrum and to undertake longitudinal and detailed analysis, to create a complimentary set of examples of circular innovations.

Thirdly, the cases that we have evaluated, which represent a non-exhaustive sample of 120, with further refinement to a cohort of 90 able to withstand our simplistic analysis, are likely to represent only a small proportion of the circular innovations, that may be currently classified as environmental initiatives, sustainable or responsible innovations. Therefore, before we attempt to collect any more examples of circular innovations, a more sophisticated and rigorous methodology must be created, perhaps including a temporal dimension, to be able to consider product/service maturity or potentially organisational maturity. Likewise if we are able to study these cases in more detail with a more sophisticated instrument we may be able to identify the core elements that make up a truly "circular innovation" with the potential to create value at a broader systems-level. Accordingly, if we can establish this, we may be able to identify the variances to the construct of Innovation Management Capability which organisations require to be able to develop these innovations again and again.

Limitations to this research and our contribution

We do not argue for the generalisability of this work and in doing so we acknowledge that the classification of the cases into these frameworks and heuristic is not fine grained enough to offer repeatability. We therefore assert out contribution here is to apply examples of existing frameworks to provide context and nuanced definitions of the Circular Economy and Circular Innovations, that can be used a starting point from which innovation and entrepreneurships scholars can build accordingly. We therefore encourage researchers to criticise our technique and to build more rigorous instruments from which to define circular innovations, determine how products may move to diffusion and to scale in the CE context and how organisations can build the requisite capabilities to deliver these regularly and successfully.

7 References

ADAMS, R., TRANFIELD, D. & DENYER, D. 2011. A Taxonomy of Innovation. *International Journal of Innovation Management,* 15**,** 359-392.

BARNEY, J. 1991. Firm resources and sustained competitive advantage. *Journal of Management,* 17**,** 99-120.

BESSANT, J. & TIDD, J. 2011. *Innovation & Entrepreneurship* Chichester, John Wiley & Sons.

BLOMSMA, F. & BRENNAN, G. 2017. The emergence of circular economy: A new framing around prolonging resource productivity. *Journal of Industrial Ecology,* 21**,** 603-614.

BOCKEN, N. M., OLIVETTI, E. A., CULLEN, J. M., POTTING, J. & LIFSET, R. 2017. Taking the circularity to the next level: a special issue on the circular economy. *Journal of Industrial Ecology,* 21**,** 476-482.

BOULDING, K. E. 1966. The economics of the coming spaceship earth. *Environmental Quality Issues in a Growing Economy*.

BRAINARD, S. L. 1993. A simple theory of multinational corporations and trade with a trade-off between proximity and concentration. National Bureau of Economic Research.

BRUNSWICKER, S. & VANHAVERBEKE, W. 2011. Beyond Open Innovation in Large Enterprises: How Do Small and Medium-Sized Enterprises (SMEs) Open Up to External Innovation Sources? *Available at SSRN 1925185*.

CHESBROUGH, H. 2013. *Open business models: How to thrive in the new innovation landscape*, Harvard Business Press.

CHRISTENSEN, C. 2013. *The innovator's dilemma: when new technologies cause great firms to fail*, Harvard Business Review Press.

COOPER, R. G. & KLEINSCHMIDT, E. J. 1987. New products: what separates winners from losers? *Journal of product innovation management,* 4**,** 169-184.

GEISSDOERFER, M., SAVAGET, P., BOCKEN, N. M. & HULTINK, E. J. 2017. The Circular Economy–A new sustainability paradigm? *Journal of Cleaner Production,* 143**,** 757-768.

GHISELLINI, P., CIALANI, C. & ULGIATI, S. 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production,* 114**,** 11-32.

HARGADON, A. 2003. *How breakthroughs happen: The surprising truth about how companies innovate*, Harvard Business Press.

HATCHER, G. D., IJOMAH, W. L. & WINDMILL, J. F. 2012. Design for remanufacture: organisational factors influencing successful integration into the design process. *Design for Innovative Value Towards a Sustainable Society*. Springer.

LAFORET, S. 2008. Size, strategic, and market orientation affects on innovation. *Journal of business Research,* 61**,** 753-764.

MCADAM, R., REID, R. S. & GIBSON, D. A. 2004. Innovation and organisational size in Irish SMEs: An empirical study. *International Journal of Innovation Management,* 8**,** 147-165.

MURRAY, A., SKENE, K. & HAYNES, K. 2017. The circular economy: an interdisciplinary exploration of the concept and application in a global context. *Journal of Business Ethics,* 140**,** 369-380.

ROTHWELL, R. 1992. Successful industrial innovation: critical factors for the 1990s. *R&D Management,* 22**,** 221-240.

RUGMAN, A. M. & VERBEKE, A. 2004. A perspective on regional and global strategies of multinational enterprises. *Journal of international business studies,* 35**,** 3-18.

STAHEL, W. R. 2016. The circular economy. *Nature News,* 531**,** 435.

STEFFEN, W., RICHARDSON, K., ROCKSTRÖM, J., CORNELL, S. E., FETZER, I., BENNETT, E. M., BIGGS, R., CARPENTER, S. R., DE VRIES, W. & DE WIT, C. A. 2015. Planetary boundaries: Guiding human development on a changing planet. *Science,* 347**,** 1259855.

TIDD, J. & BESSANT, J. 2009. *Managing Innovation: Integrating Technological, Market and Organisational Change,* Chichester, John Wiley & Sons Ltd.

TIDD, J. & BESSANT, J. 2015. Innovation and entrepreneurship.

ULWICK, A. W. 2005. *What customers want: Using outcome-driven innovation to create breakthrough products and services*, McGraw-Hill Companies.

WAN, D., ONG, C. H. & LEE, F. 2005. Determinants of firm innovation in Singapore. *Technovation,* 25**,** 261-268.

WEBSTER, K. 2017. *The circular economy: A wealth of flows*, Ellen MacArthur Foundation Publishing.

Annex 1

Case ID	Location	Company Size	Brief Explanation
CE1	US	Start-up	Vertical farming using hydro and aeroponics
CE2	UK	Small	Examines the implications of circular design on products
CE3	Brazil	Small	Clothing lines made from recovered textile -and much more
CE4	US	Medium	Chemical technology for lead acid battery recycling
CE5	Italy	MNLE	Production of nylon yarn from waste materials
CE6	US	MNLE	Take back schemes for ceilings
CE7	UK	Small	Online marketplace allowing recycle of wardrobe
CE8	UK	Medium	Independent remanufacturing in the automotive industry
CE9	Denmark	Micro	Finding a fast fashion model that works, reusing leather
CE10	UK	Medium	Recycling waste coffee grounds into advanced biofuels
CE11	Hungary	Start-up	Decentralised, living factories to address urban sustainability problems
CE12	Global	MNLE	Large scale transition from a manufacturer to a collector and re-user of garment hangers
CE13	UK	NLE	Factory scale industrial symbiosis factory to eliminate waste and increase revenue
CE14	UK	Medium	Valuable resources extracted from used cooking oils
CE15	Netherlands	Small	Delivering household appliances as a service
CE16	US	NLE	Largest remanufacturer of auto parts in the world
CE17	Global	MNLE	Remanufacturing of heavy equipment
CE18	Brazil	Micro	Alternative materials/business models - single use packaging
CE19	UK	Micro	Financing the circular economy
CE20	Malaysia	MNLE	Measure and manage energy use using IoT
CE21	Brazil		Bottle caps which are ready to be upcycled as Lego-compatible building blocks
CE22	US	MNLE	Increasing post-consumer plastic content in packaging
CE23	US	NLE	Reverse Logistics Supply Chain Service Solutions
CE24	France		Watershed resotoration protect water quality, improves farming practices and creates jobs
CE25	France	MNLE	Aiming for a fully cradle-2-cradle product line in the carpet sector
CE26	Canada	Medium	Custom pre-fabricated interior construction solutions ('more than just movable walls')
CE27	UK	MNLE	Ambulance remounting program
CE28	Copenhagen	MNLE	Car sharing service including zero emission vehicles
CE29	Netherlands	NLE	Produces and recovers carpets
CE30	US	Medium	Mushroom derived alternatives to petroleum based packaging
CE31	Europe	MNLE	Pay per wash model as an alternative to ownership
CE32	Europe	MNLE	Rental and maintenance of textile and hygiene articles
CE33	US	Medium	IoT based energy service system
CE34	Europe	Medium	Leading WEEE service provider for re-use and recycling efficiency
CE35	US	Micro	Technology turning old textile Fibres into new garments
CE36	US	MNLE	Portable/urban/verticle farming
CE37	US	Start-up	Access over ownership model for quality furniture
CE38	US	NLE	Games console retailer shifts to remanufacturing model
CE39	Global	Micro	Nappies redefined - reusable outers, compostable inserts
CE40	Global	MNLE	Energy-as-a-service platform

CE41	NL	Start-up	Subscription model for modular, easy to dissasemble headphones
CE42	UK	Micro	Reuse unwanted items with businesses, charities and people
CE43	US	MNLE	The circular economy and the promise of glass in concrete & Large Data Centres
CE44	Global	NLE	In store collection for re-use and recycling
CE45	USA	MNLE	Instant Ink
CE46	France	Small	Animal feed for aquaculture from agricultural by-products
CE47	India	NLE	Transformation of food waste into nutrients
CE48	Singapore	MNLE	Air con as a service (ACaaS)
CE49	UK	Small	Leading supplier of compostable and recycled packaging to the food and catering industry
CE50	Denmark	MNLE	Using product passports to improve the recovery and resue of shipping steel
CE51	UK	NLE	Collection, refurbishment and resale of mobile phone handsets
CE52	UK	Medium	Remanufacturing of automotive engines and gearboxes
CE53	France	MNLE	Fleet management and remanufacture of tyres
CE54	Taiwan	Small	Turns post-consumer waste into high performance material
CE55	Netherlands	Start-up	Leasing model for organic jeans
CE56	US	Start-up	New kind of leather grown from mycellium and agricultural by-products
CE57	Brazil	Start-up	Pioneering circularity in durable consumer goods
CE58	Global	MNLE	A new approach to Nike's supply chains to improve efficiency and innovation
CE59	US	Medium	Phosphorus recovery from wastewater
CE60	US	MNLE	Common Threads initiative
CE61	Netherlands	MNLE	Lighting as a service
CE62	Netherlands		Generating electricity with living plants. Could provide clean power to remove communities.
CE63	Netherlands	Start-up	Urban Biotopes - helping plants achieve their full potential
CE64	Brazil	NLE	Reducing structural waste in construction
CE65	Sweden	NLE	Extraction of bio-chemicals from forest biomass
CE66	Netherlands		Reuse workwear to make bags, with a material passport and can be returned.
CE67	Japan	MNLE	Platform-based products and availability-based contracting
CE68	UK	Small	Reverse supply chain for electronics
CE69	Israel	Start-up	Re-inventing paper as part of the Circular economy
CE70	UK	Medium	Remanufacturing of refuse vehicles
CE71	France	MNLE	Short loop recycling
CE72	US	Micro	Turns textile waste into garments
CE73	US	Start-up	Reusable washing liquid bottle
CE74	UK	Small	Hydrogen fuel cell car as a service model
CE75	Switzerland	NLE	Climatex lifecycle - synthetic fibre, non-toxic dyes
CE76	UK	Micro	Circular models in office furnishing
CE77	Israel	MNLE	Reduces consumer packaging
CE78	UK	Small	Rethinking the business model for cleaning products
CE79	UK	Start-up	Brewing beer from surplus bread
CE80	Norway	NLE	Sensor-based solutions to optimise reverse logistics and resource productivity
CE81	Brazil	NLE	Adopting a systemic approach to design out waste
CE82	China	MNLE	Recycling of PV modules
CE83	Japan	MNLE	Maximising durability of clothes

CE84	US	NLE	Magnet manufacturer/recycler using scrap magnet as feedstock
CE85	Denmark	Start-up	Subscription model for baby clothes
CE86	Bangladesh	MNLE	Garment manufacturer implementing energy efficiency from spinning to garment production
CE87	Germany	Start-up	Bio-engineering waste to chemicals
CE88	US	Micro	Integrated system, cascading
CE89	UK	Start-up	New clothes from end of life clothing
CE90	US	MNLE	Mobility on demand