

Department of Business and Management Professorship of "Corporate Strategy"

The Strategic ratio behind the Circular Industrial Model: perspectives on the Smartphone Industry

Supervisor: Prof.ssa **Federica Brunetta**

Candidate:

Guido Di Luigi

Matr. 689261

Co-supervisor:

Prof. Alessandro Zattoni

Academic Year 2017/2018

Table of Contents

Introducti	on	.3
1. The	Circular Economy and the Circular Industrial Model:	
Explorii	ng a new Framework	. 5
1.1 7	The limits of linear consumption: take-make-dispose	. 8
1.1.1	Resource losses of the linear industrial model	12
1.2 H	Basic principles and school of thought underlying the Framework	15
1.3	The shift from consumption to usage	18
1.4	The circular Economy's general Industrial Scheme and its sources of value	21
1.5 I Enabler	s the global economy mature for adopting a Circular Industrial Framework?	26
1.5.1	Technological advancements and intelligent asset	26
1.5.2 Econe	Consumer preferences and socio-demographic trends: the "Sharing omy" and its implications for the circular economy	30
1.5.3	Governments awareness and innovative policies	32
1.5.4	Principal Barriers for Circular Economy	35
2. Reve	erse Logistics and Looping Supply Chains: an overview	38
2.1	The basic principles underlying a Closed-loop Supply Chain	39
2.1.1	Activities, risks and flows within a Closed-Loop Supply Chain	41
2.2 F strategie	Product Design and Closed-loop Supply Chain as a Core Competency: c implications	44
2.2.1	Quality, Durability and Maintainability strategy	45
2.2.2	Multiple Lifecycles Strategy	46
2.2.3	Single Lifecycle strategy	47
2.2.4	Third-party Reuse	47
2.3 T	Third-party vs. Original remanufactured products: a behavioural analysis of her perceived value	49
2.4 Outsour	Corporate strategies and Reverse Logistics: Vertically integrated, Hybrid and rced Closed-Loop Supply Chain strategies	l 51
2.4.1	Vertically integrated CLSC Strategies	52
2.4.2	Outsourcing CLSC strategies	53
2.4.3	Hybrid CLSC strategies	54
2.4.4	Putting all together: choosing the right CLSC strategy	55

S	chen	nes: t	he case of Dell and Genco ATC			
	2.5	.1	Pricing Scheme			
3.	A	circ	ular industrial model for Consumer Electronics	••••		
3	3.1. Electrical and Electronic Equipment: Waste streams and Consumption tren 63					
	3.1	.1	The value of global WEEE streams			
	3.1	.2.	Mobile phones and waste streams: some figures			
3	3.2	Tak	ing the Electronic Industry Away from the Linear Industrial Model	••••		
	3.2	.1	Reverse Logistics and EEE			
	3.2	.2	Patents and Technology Licensing within a closed loop environment	••••		
	3.2	.3	Design Strategies	••••		
	3.2	.4	Standardisation: implications on circular practices	••••		
	3.2	.5	The diffusion of Cloud Computing	••••		
	3.2	.6	User Perception			
	3.2. cou	.7 Ild be	Residual Value: how virtuous loops that speed up the adoption proces ignited	5S		
3	3.3	Sm	artphones and Circular Economy: current trends	••••		
3	3.4	Ap	olying the Framework: the example of FairPhone	••••		
	3.4	.1	Fairphone 2: concept and architecture	••••		
	3.4	.2	Fairphone 2: Design-for-Upgradeability	••••		
3 s	3.5 mart	Put phon	ting things together: a strategic approach towards circularity within the e industry	; 		
	3.5. mai	.1 inten	Location of the facilities and centralisation: the key role of predictive ance	2		
3.5.2 strategie 3.5.3		.2 itegie	Towards smaller loops: decentralisation of the activities through design es			
		.3	The last building block: cascading strategies through customer segme 102	nt		
Co	nclus	sion.		•••		
Bib	oliogi	raphy	7	•••		
Ind	lex of	f figu	ıres	••••		

Introduction

This dissertation aims at exploring the potential for the manufacturers of Consumer Electronic Devices of putting in place practices in line with the Circular Industrial Model. Underlying the whole research topic there will be the concept of the Circular Economy: a restorative industrial model, where products are designed and intended to be readily reused or disassembled to be, at that point, either easily refurbished or recycled. The difference is remarkable: within the circular economy framework the reuse of materials and their residual utility along several industrial cycles– at a product, component or material level –is the foundation of the economic growth.

As the pace of innovation decreases and Smartphone Industry appears to be approaching a mature phase of its cycle, Original Manufacturers have the chance to put in place Closed-loop Supply chains systems to seize and exploit the value of the existing devices over multiple lifecycles. As the value of wasted mobile phones is more than 9 bln euro worldwide and both second-hand and remanufactured devices markets are rapidly growing, there is a risk of leaving third parties building a competitive advantage in reverse logistics activities – such as product acquisition, testing, inspecting, remanufacturing and re-commercialization.

In the first chapter, the Circular Economy framework will be explored with respect to its main differences with the actual linear system, the basic principles underlying it and the sources of value creation that can be unlocked. Main pivotal concepts of the chapter are the importance of product design with respect to value recoverability, the exigency of shifting from post-sale consumption to service-based usage, the concept of prioritise end-of-life treatments based on residual value or utility – known as "cascade" and also how technology and recent policies can accelerate the transition towards circular systems.

In the second chapter, a more down-to-the-earth approach to the Circular Economy will be treating the concept of a Closed-loop supply chain as the merge of the classic forward logistics with the reverse logistics: the process of implementing and controlling cost-effective flows of value from the consumption stage back to its origin - being the manufacturer or the retailer – aiming at minimising losses through recapturing value. The pivotal concepts that will be outlined are the interplay between design strategies, reusing

activities – at any level - as core competences, the role of third parties and corporate strategies that better balance the complex interrelations entailed.

In the third chapter, the focus will be moved towards Consumer Electronics Industry. An overview of the valuable global waste streams and their main drivers will introduce to the actual drivers for the adoption of a Circular Industrial model. Design strategies and modularisation will be outlined and made clear with the case of "Fairphone 2". In addition, factors such as the consumer acceptance of remanufactured devices and also the diffusion of Cloud computing – and its effects on decreasing the performance demand on devices – will be deepened. In the second part of the third chapter, the focus will move completely towards smartphone industry with an overview of the themes, current trends and challenges with respect to Circular Economy adoption. In the very last section, all the concepts analysed in this work will be meshed to create a model for the Smartphone manufacturers to achieve a Multiple Lifecycles strategy, with all the managerial implications on control over the supply chain and design strategies.

1. The Circular Economy and the Circular Industrial Model: Exploring a new Framework

In this chapter, the concept of "Circular Economy" and its ever-evolving framework will be explained as a conceptual guide for the topics of the next chapters but also to work as an imprinting of the philosophical and economic regime – that I consider fascinating – it is all based on. In other words, though the concretization of this framework on a large scale might seem a hard path, but the awareness that a change in this direction is possible and needed might be the most effective trigger of further innovations both in terms of technology – we will mention reusing potentials and backward logistics – and business models – one above all, the radical switch from producers to service providers.

The environmental signs of the resource depletion that has been conducted in the last decades keep becoming more and more evident. Even though one could argue that those impacts on our biosphere and society could alone represent the main drivers in fostering a change, other hard reasons are needed to effectively influence the behaviour of the main economic actors and policy-makers – and not just in a cosmetic way. For this reason, I decided to exclude any consideration on environment and pollution since - rather than just facts - are often considered the product of moral rather than factual reasonings. The exigency for a new economic and – over and above – industrial model comes from the increasing prices of the raw materials along with their volatility. As it will be explained further, the trends that are being followed in this century by global input prices are making many companies aware of the risks they are exposed to in terms of profit margins – there is also the theme of the always more expensive hedging contracts – and supply disruptions.

The idea of a "Circular economy" does not have unique sources but it is the result of innovative ideas coming from an uneven set of academics, thoughts-leaders and business visionaries. Economists, industrial designers, chemists, biologists started to look at the economic structure and functioning as something that cannot be considered fully linear –

namely extraction, transformation, consumption and disposal of resources – and isolated – therefore not impacted by what happens after the consumption - but, as any biological phenomenon, something that is deeply connected with the overall natural and sociological system it takes place in.

It is a restorative industrial model, where products are designed and intended to be readily reused or disassembled and either easily refurbished or recycled. The difference is remarkable: within the circular economy framework the reuse of materials and their productivity along several - rather than a single - industrial cycle is the foundation of economic growth. Since the framework goal is minimizing new input to the value chains, unlimited resources like labour and renewable energy sources take a central role while resources characterized by natural supply limitations are reserved more of a secondary and supporting role.

The Ellen McArthur Foundation (EMCF) can be considered the first real think-thank focused on the exploration of the opportunities connected to the innovative concepts of "circular economy" and its promotion. It was founded in 2010, managed and advised by "McKinsey and Co." and supported by major firms such as Cisco and Renault. Thanks also to the foundation's extensive work, many big players - like Unilever - have acknowledged the strategic consistence of this framework. In its very first report, EMCF estimated over a 50 years span that – for example just in the medium-lived complex products industries - the application of CE principles would represent an opportunity of potential material savings of more than USD 300 billion delta with the expected Business-As-Usual material consumption at the European level for a not at all radical "transition scenario" (Ellen MacArthur Foundation, 2012) . In a second report, focused on the consumer goods sector, estimation on the potential opportunities of introducing effective circular measures reached USD 700 billion - about 20% of the material input costs incurred by the industry- with particular focus put on the packaging practices (Ellen MacArthur Foundation, 2013). With respect to the European Economy, adopting a circular industrial model is supposed to generate a net economic benefit of EUR 1.8 trillion by 2030, an increase in house income of EUR 3000 on average and a halving of the carbon dioxide emissions, according to an estimation (Ellen MacArthur Foundation, 2015)

1.1 The limits of linear consumption: take-make-dispose

An industrial model is considered "linear" when the characteristics of a classic inputoutput cycle can be recognised in it:

- Extraction of materials
- Application of energy to manufacture components and subsequently products out of them
- Sell to an end consumer
- Ultimate and most of the times irreversible post-consumption disposal

Although resource efficiency tends to increase over time, any system based on a linear model of resource consumption rather than on a restorative exploitation of resources entails - by definition- long term and aggregated losses across all the value chain (Ellen MacArthur Foundation, 2012). As long as the industrial model will remain mainly linear, efficiency can be improved just on single components and therefore without reaching a comprehensive and systemic solution. Efficiency across the value chain can – dramatically speaking – just delay the inevitable and natural consequences of exploiting finite resources. Moreover, in 21st century raw materials prices are rising along with their volatility, implying heavier costs for the inefficiencies that will be explored in the next section.





Figure 1.1 Accenture (2014), Accenture analysis based on data from World Bank, Commodity Price Data (The Pink Sheet), April 2014 version

The beginning of the century has seen a new trend in the growth and resource use dynamic. If in the 20th century commodity prices had been inversely related to economic growth (Figure 1.1) – every 1% growth in GDP was accompanied by a 0.5% decrease in the price index-, something changed when the relation became directly related, with the commodity price index rising by 1.9% each 1% growth in GDP (Accenture, 2014).

As we are speaking of GDP growth and material consumption, we can draw by the basic economic concepts how those correlates with the increase of new masses of people bound to join the global consuming class. Since also consumption preferences and lifestyle influence global demand, OECD has estimated that, by 2030, the global middle class will more than double its 2009 number (from 1.9 to 4.9 billion). 90% of that increase will be coming from the Asia-Pacific area (OECD, 2012). While below we will look at the upstream effects on the demand for raw materials and virgin feedstock inputs, the rise of this huge mass of new middle consumers from developing countries and, especially, their improved financial profiles, are expected to make the consumption to grow, in those same countries, up to 30 trillion USD each year. Each year there will be an increase in the value of what is consumed that more than doubles the variations observed at the beginning of this century: 12 trillion USD in 2010 (OECD, 2012). Another interesting fact, highlighted by EMCF (2013), is the switch towards packaged product that is predictable and in line with the development of poorer countries towards "western standards". Huge global chains, e.g. in the food sector, will inevitably increase - along with the demand - the unrecoverable wastes and the losses in the various passages needed to systematically deliver food. While food spending is likely to increase by 57%, packaging and – especially for the purpose of understanding the importance of the circular economy framework - end-of-life materials are expected to grow by, respectively, by 47% and 41% by 2025 (Ellen MacArthur Foundation, 2013).

This incredibly sharp increase is bound to cause a dramatic demand upward shock for basic resources such as oil, coal, iron ore and other naturally extracted resources - where about 90% to be attributed to emerging markets (UNEP, 2013).

Being that the linear model locks the firms and, in turn, end consumers to those upstream prices, surpluses across all the globe are being lost. Optimistic and pessimistic projection on the resource demand for limited resources (such as Biomass, fossils, energy and many metals) in 2050 range between 80 and 130 billion tons: meaning between 200 and 400% the earth annual resource capacity (Accenture, 2014). For the sake of clarity, global demand for those limited resources is right now more than 50 billion tons. With a great deal of companies locked in their upstream procurement of metals, the huge increase in demand for metals of the last decades - it almost doubled from 1980 (UNEP, Metal Recycling: Opportunities Limits, Infrastructure, 2013)- has been caused by the huge infrastructural advancements across all the globe as well as the electronic revolution. Moreover, UNEP has estimated that if the population of the emerging economies will adopt a similar set of technologies and consumer preferences and lifestyle, the metal required globally to satisfy the demand would be 3-9 times the 2013 value (UNEP, 2013). Growing demand is bound to push metals production towards the end of their cost curves, where small demand shocks can lead to disproportionately high increases. In parallel, higher technological requirements will be needed to exploit reserves that are more difficult to reach (oil, gas, zinc and gold) and, simultaneously, increasing the probability of disruptions and so costs to be charged downward in the value chain.



Figure 1.1 Estimated depletion over time of the main industrial materials and recycling rates at 2013. Source: Professor James Clark, Green Chemistry, The University of York (Clark & Hunt, 2013)

Researchers from Cambridge pushed it further, predicting a whole spectrum of key elements that will be depleted within the next 40 years – among which gold, silver, indium, iridium, tungsten and others of huge strategic importance for many industries – figure 1.2 (Clark & Hunt, 2013).

The combination of high and volatile prices on commodities make firms incur in profit squeeze that gets more sever as the elasticity of the demand rises - since the increases cannot be charged downward in the chain. In addition, firms that rely on hedging contracts to stabilize their costs incur in higher financial fees that are well connected to the expected volatility of the prices. Because of that, new theoretical constructs aiming at decoupling the sales revenue from material inputs parameters are being discussed and developed.

1.1.1 Resource losses of the linear industrial model

The previous century low real prices for natural resources has been a huge support for the economic growth of advanced resources (McKinsey, 2011). The new century found to be inverting this tendency, spreading light to the wasteful system of resource management that has uncarefully been put in place. Before the rise of fiscal regimes that were predicting indirect costs associated with energy and some materials, the biggest gains in economic efficiency consisted mainly in substituting the labour cost with more resources, especially energy. The ease of procuring new materials and the absence of considerable economic and legal constraints on their disposal are the main drivers of the resulting "linear" industrial model.

Inefficiencies in the production chain were estimated to be around 21 billion tonnes of materials that are consumed by the producers but not eventually incorporated in the final products1 (Ellen MacArthur Foundation, 2012). In other words, a huge amount of lost value that has been extracted, bought and, maybe, also transported, but has never entered the economic system. With respect to the food sector, a FAO commissioned research assessed these losses to one-third of food production for human consumption every year (J. Gustavsson et. Al, 2011).

Looking at the post-disposal stage, a UNEP report took a snapshot of the recycling conditions of a panel of 60 metals and found out that only 20 or so presented a recycling rate of at least 25%. Moreover, looking at metals with high recycling rates (Copper, gold,

¹ Materialsflow.net, data extracted by the Sustainable Europe Research Institute (SERI);

aluminium and silver), there is still consistent value lost (UNEP, Recycling Rates of Metals - A status Report, 2011).

Speaking about end-of-life waste, another example of inefficiencies comes from the building sector. Out of the 615 mln tonnes of waste across all US, construction and demolition waste accounts for 26%. Out of those 160 mln tonnes, only a 20 to 30% portion is actually recycled or reused. The spare 110-130 million tonnes represent a huge loss of value: e.g. 40-50 million tonnes of lumber that could be easily turned into wood flooring or new construction material. The rubbles from the demolitions are more difficult to break down into parts, differentiating into reusable components or recyclable materials, when an upstream design is not conducive to an easy and cheap second-hand exploitation (US EPA, 2009).

There is also the theme of the energy usages. On one hand, from an almost physical point of view, landfill disposal – in Europe in 2014 accounted for the 47% of the total "treated" waste - means a total loss of the residual "scrap" energy (Ellen MacArthur Foundation, 2012). While incinerating or recycling those products translate in a quite small recoupment of the energy, reuse saves way more energy since the full potential of that product/component is almost fully expressed through an extension of its utility over time. On the other hand, within the linear industrial model, the majority of energy usage is concentrated along the upstream levels of the value chain, where the materials are extracted and converted to commercially usable items. Passing to a circular framework would mean strongly cut the energy usage. With respect to aluminium, the fact that 80% of energy consumption and 67% of total costs occur in the refinement and casting phases - therefore implying new materials as inputs - has had a positive impact on its end-of-life recycling rate, ranging between 43% and 70%, more than the other non-ferrous metals (McKinsey, 2011).

A systemic view that – as already mentioned is vital to comprehend and put a circular model in practice - imposes to a company to revise its own energy sources and start to rely on energy from renewable sources. In 2011 Walter Stahel – whose ideas will be explored in the next paragraphs - proposed a shift in taxation from labour to not-

renewable energy and material consumption would foster the adoption of circular business models and, at the same time, the efficiency pressure would be shifted towards material consumption and energy sources that represent true bottleneck of our society/economy (EMCF, 2012). In the long term there is no scarcity of labour nor renewable energies, a circular system that is projected in wide time spans should choose predominantly those productive factors over finite virgin materials.

1.2 Basic principles and school of thought underlying the Framework

The concept of a restorative circularity within an industrial system has its roots on the study of non-linear systems such as the ecosphere. We have already mentioned that increase efficiency – both in terms of resources and energy consumption – represents a component rather than a system optimisation. In trying to take this systemic view, we shall start to think to the industrial process more as a flow of materials that – influentiated by imprecise condition and feedbacks – leads to unproportionate outcomes. McDonough and Braungart (2002) clustered these material flow in:

- Biological nutrients: bond to join the biosphere again and continue their biological life by building natural capital
- Technical nutrients: designed upward to circulate and express their utility in the biosphere but without entering it. It is interesting to note how this view already puts a lot of pressure on the disposal of technical nutrients. Should a product made of technical nutrients be designed to avoid being disposed and, therefore, join the biosphere and lose their utility and energy potential?

Cradle-to-Cradle" is a term that – though invented by Stahel – became famous thanks to the book "Cradle-to-Cradle: Remaking the Way we Make Things" of 2002. Flow of industrial materials should be modelled and inspired to the "biological metabolism". Particular emphasis is put on the knowledge of the molecular composition of every input in order to put in place quality-based materials recycling systems. Here is that product components shall be designed for continuous use-cycles within a wider view aiming at developing a "technical metabolism" flow of industrial materials – namely, technical nutrients (Braungart & McDonough, 2002).

If one-way linear product-life-cycle represents the enemy, the extremes – virgin materials and waste - should be "bended" in order to create a loop. Waste shall be designed out. Within the circular economy framework wastages are treated as both a process and product design problem. Here again we have a parallel with the biological

cycle since both biological and technical components, should be designed to fit within a material cycle. Biological nutrients, because of their compostability (and therefore, also biodegradability), can easily be inserted within various bio-chemical processes because of their non-toxic nor hazardous nature. Technical nutrients need to be designed to fit as efficiently as possible, in terms of energy and quality retention, in a downward process to be disassembled, refurbished or recycled. Modularity should aim, e.g. with respect to technological products, to be able to disassemble and recover easily some components for upgrades or for the next generation. In 2015 the British authorities, in assessing the impacts of their environment, food and Rural affairs policies also gave us a feedback on the aggregated effects of what has been called "eco-design". In transposing the European "Ecodesign Directive 2009/125/EC" on the design of energy-related products, the British department observed that each pound invested in promoting and performing eco-design practices generates 3.8 times that in earnings for the economy (DEFRA, 2015), making it a strongly viable policy from an economic point of view.

If few principles may give a general idea of the framework, the concept itself has its roots back in the 1970s. In the next lines, a brief overview of the other schools of thought that – apart from the "performance economy" by Walter Stahel" and its key intuition of a functional service economy that will explore below - ignite the momentum of the framework. Those are the "Regenerative Design", "Industrial Ecology" and "Biomimicry".

In line with the systemic view, professor John T. Lyle challenged his students to base their activities on the value of living within the limits of available renewable resources without environmental degradation. From this idea, the "regenerative design" term is associated with all systems that comprehend in their processes renewal or regeneration mechanisms for the energies and materials they consume.

"Industrial ecology" (Frosch & Gallopoulos, 1989) is a methodology consisting in material and energy flows that are studied through industrial systems. It also focuses on the "industrial ecosystem" approach: consumption of energy and materials to be optimized where waste, spare energy and discarded materials of any nature from one

process shall be considered input for another. The impact of each process and component of the chain is analysed in terms of systemic impact and new ways of conciliating the flows of material and energies – such as the closed loop processes – are studied. With a systemic point of view, local ecological constraints and the global impact of the operations should drive the product design.

"Biomimicry" (Benyus, 2002) is but a knowledge-based approach that aims at learning from nature, after his remarkable experience in failing, adapting and succeeding. If nature works with low or no energy, no inventory, material efficiency and at ambient temperature companies can just hope to coupe some of that expertise. Along with the design and process specification, nature shall be used also as a measure or ecological standard to judge the systemic performance of a process in terms of sustainability.

1.3 The shift from consumption to usage

A systemic thinking is vital to embrace the framework. Walter Stahel's "The Potential for substituting manpower for energy" started to build in 1976 (Though published in 1981)– as a report for the European Commission – what we now call "Performance Economy" and contributed to legitimate an alternative vision of an economic system in loop along with the expected impacts on employment, competitiveness and – of course – on resource saving and waste prevention. A globalisation of the actual industrial economy's business model is marked by Stahel as not compatible with a global future nor with the predictable evolution of the availability of our finite resources (Stahel, Jobs for Tomorrow, the Potential for Substituting Manpower for Energy, 1981).

Analysing flows and connection over a wider time span are important to foster regenerative circular conditions. If the focus shall be widened up from a single component of an isolated chain, consumption stage is not exempt from critics on its role. There is no thing such an end consumer, one-way consumption is one of the main enemies of the framework. Because of that, the idea of a "functional service model" where manufacturers/retailers share the use of their products/assets, retaining their ownership: shift of the consumer to user and the supplier as a service provider, they are part of a continuous system (Stahel, 1981).

The functional service economy is characterised by an "Extended performance responsibility": e.g. consumers buy 2 years of a good that the service provider guarantees to maintain at its maximum utility level. As a consequence, the revenue structure will shift towards services.

The shift from consumption to usage would have direct implications on products and business models that entail take-back systems and ease of disassembly and refurbishment. Resource security risk, caused by the increasing prices of 21st century, can be, doing so, tackled down: causing the goods of today being the resources of tomorrow at the prices of yesterday. The performance economy has been defined also as a "Lake Economy" to

recall the concept of a self-sufficient economic system that loops on himself, adapting on re-using what is already available on the inside (Stahel, 2006).

On a profit-maximisation view, some simple imperatives can be drawn upon these concepts:

- Do not repair what is not broken
- Do not re-manufacture what can be repaired
- Do not recycle what can be re-manufactured

The third appear to be the most financially and resource wise, in line with the "physical" and economic loss of disposing or even recycling what could be reused. On one hand, Pivot activities to close the loop such as reuse, repair or refurbish are best done locally to avoid doubling the transport costs while, on the other hand, recycling is more fit to a global business based on employing cheap labour (Stahel, 2006). There is a phenomenon consisting in an informal and strongly inefficient recycling as the result of the exportation of e-waste from industrialized towards developing countries where, because of very low recovery rates (Umair, 2013), a great deal of value is lost by the global mobile phone producers (Basel-Convention, 2012). The key activities to conceive an optimal loop are stock management – therefore maintaining value and quality to preserve the performance of the assets – (Stahel, 2006), collaborative platforms (Ellen MacArthur Foundation, 2012) and contract schemes that build the right incentives to foster an "active consumption".

The pioneer in business models focused on services around a good whose ownership is retained by the producer is Michelin that in the 1920s started to provide tyres under a "pay-per-kilometre programme"; in 2011 Michelin used to offer tyre management and at the end of the usage period is able to collect them either to extend their technical life or properly recycle the most out of them (Ellen MacArthur Foundation, 2012). Another example is General Electric that, from the 1990s, earn more than 75% of its revenues from services (Stahel, 2006). Another more recent example comes from Europe where Philips serious steps towards circularity in its lighting division. It has gained through time

a controlling stake over 22 firms that perform collection and service organisations arriving to efficiently collect back 40% of the mercury-based lamps they put on the market. That same mercury is extracted and used back into new products with a 95% recycling rate: this makes that key material increase its economic and strategic productivity over various product life-cycles (Ellen MacArthur Foundation, 2014). If the road towards a circular business model had been already taken, is even more recent their switch towards a business model that entails selling lighting as a service rather than a product. On one hand costumers avoid the upfront costs such as installing and warranties and – at the same time – are ensured about items that will be steadily performing over the whole contract period, on the other hand, Philips ensures a just environmental management over the end-of-life stages of the items whose – therefore – ownership is retained. Over and above, Philips lighting is an example of a working and finely tuned business model that legitimate a firm, economically and strategically, to invest in its circularity to gain real benefits in terms of material costs rather than just cosmetic changes ("being environmentally just") that impact on its brand image.

1.4 The circular Economy's general Industrial Scheme and its sources of value

In the figure 1.3, prepared by EMCF, we can have an idea of the circular processes that can affect both biological and technical nutrients. For the purpose of this elaborate, we will focus on the technical side of the scheme. Above all, it is interesting to finally have a visualization of what we had before called loops and whose closure represents the main framework's challenge. Mining and materials manufacturing as well as the landfill appear marginal in the reflecting their being in the framework the extremities of the linear industrial model to be minimised as value losses.



Figure 1.3 Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition; Ellen McArthur Foundation, 2012.

Once the parts have been manufactured and assembled into products a service provider will supply them to the users. To restore its original utility the user can always make the

item go through a maintenance process following either the process designed by the producer – as a new service purchased, a basic warranty or a performance contract where the service provider takes care of the maintenance as part of the deal e.g. in leasing contracts – or following other ways like unauthorised sellers or "do-it-yourself".

Everything that cannot be just maintained, that is perceived at the end of its life by the consumer – also if still functioning – or that a consumer wants to simply be changed represents a stock of value to be seized by the producer, the provider or even a third party. What EMCF calls cascades – or loops – of components and materials can, at that point, start: those are put in different uses after end-of-life across different value streams and extracting over time components, materials and energy that is stored in them. As the original units of value go through the path, their material order, utility and/or quality decreases.

Systems of reverse logistics as well as contractual incentives need to be put in place in order to prevent the user from disposing the good. At this point there are various alternatives:

 Goods that can be reused at an equal level of utility – if lower, above an acceptable threshold – can be "looped back" to the service provider/distributor in order to be sold on the secondary market or redistributed as a lower-class product

The next activities will be controlled either directly or outsourced by the product manufacturer and, therefore, we can think that the loop gets bigger with respect to maintenance as the costs associated with it.

Some goods need to undergo a refurbishment process of its good working condition. Refurbishment happens through, for example, replacing or repairing the major components that are either completely or almost faulty. Since the product is supposed to look new, of course other cosmetic changes on its appearance are needed. With respect to contractual terms, if warranty would be shorter than the one for new products is more likely to cover the whole product.

If the refurbishment is a product level intervention, remanufacturing is a process that consists in disassembling and recovering the subassembly or smaller components level. When remanufacturing happens, it is because the majority of the product is considered not worth a refurbishment. Therefore, just functioning and reusable parts will be drawn out of the used products and rebuilt into a new one. So, refurbishment can, as roof performance, just reply the initial quality level of a product while remanufacturing can include changes and enhancements to the components.

Three years ago, in 2015, the European market for the main remanufacturing intensive sectors was EUR 1.5 trillion according to an European Commission study. The main European market have been the Aereospace (EUR 12.4 bln), the Automotive (EUR 7.4 billion) and the Electronic and electrical equipment one (EUR 3.1 bln) (Eropean Remanufacturing Network, 2015).

What cannot undergo the above-mentioned processes as well as what are theirs waste and spare parts shall be directed to the parts manufacturer or, before him, his material supplier to be recycled.

- Downcycling is the recycling process of converting the initial inputs into materials of lesser quality and/or reduced functionality.
- Upcycling is the recycling process of converting the inputs into new materials of higher quality and/or increased functionality.

Stating that leakages of this process should be kept to minimum – as a matter of efficiency – it is naturally predictable that a portion of matter will be forced out of the loop/cascade each time this is performed. This mass can be considered the defeat of the circular economy framework and, as the technology proceeds and the business models and processes undergo incremental and innovative improvements, should tend to the physical

limits of the energy and matter dispersion. At this stage, what we have is an unrecoverable waste whose treatment has few options:

- Energy recovery is the conversion of this unrecoverable and unrecyclable waste materials into other physical forms such as heat, electricity or fuel. The process is called "waste-to-energy" (Ellen MacArthur Foundation, 2012). Even if undesiderable, this option still consists in turning a not useful resource in a useful one and, therefore, somehow still pursuing the ratio behind Circular Economy.
- The same does not hold true for Landfilling, the extreme weapon of waste management. The unrecoverable waste together with the waste coming from the Energy Recovery process is stored into a controlled deposit of solid waste.

Now that we have outlined a general view of the phases of a circular and restorative industrial system, we can better identify the sources of potential economic value. Stated that the consistency of this value differs for different products, components and materials, four general principles based on a classification made by the Ellen McArthur Foundation (Ellen MacArthur Foundation, 2012) can still be drafted:

- 1. Power of the inner circle. The smaller the circles, the larger the savings to perform circular practices in terms of transportation costs, material, labour, energy and capital.
- 2. Power of circling longer. Value creation from increasing the life-cycle of products, components and materials within a circular model. Reducing the virgin material inflows through extending the life of a product or performing refurbishment stages results attractive for business given the rising and volatile prices of inputs. The problems regard the innovation rate that could eat up the extended life of the product and the operating and maintenance costs that need to be kept under control. Therefore, especially with product that have a consistent innovation rate, it is important to reduce at the minimum the idle time of products in the market as well as increasing the time efficiency of the loops in order to increase the prospective number of users benefiting from a fixed volume of goods (Accenture, 2014).

- 3. Power of cascaded uses and inbound material/product substitution: there is also an opportunity relative to cascading products, components and materials across different product categories. This is in line with Stahel's "Lake Economy" and "Industrial Ecology" concept. Resource value destruction has to be minimised by linking up waste from one process as valuable inputs into another production process. The value to be preserved regards also the commercial utility at the product, component and material level. The potential value creation is in the costs of the cascaded material that substitutes the virgin one with savings also in terms of embedded costs such as energy and labour. This works if the waste flows form a commercially attractive substitute for the materials that were originally used. There are now countless examples of this: rubber bands turned into slippers, coffee grounds as a nutrient medium for mushrooms, and plastic bottles as material for car parts (Stageman, 2008).
- 4. Power of pure or easier-to-separate inputs and design: the value creation potential of the above-mentioned principles can be enhanced when the purity of the material is higher or when those are collected in a segmented way, taking care of preserving purity and quality. Product damage rates and contamination of materials stream during and after the collection should be addressed. Moreover, as mentioned before, design of the product can impact on the ease of separation and a better identification of embedded and/or faulty components. All these issues should be addressed in order to reduce the costs of the reverse cycles and improve the material longevity and productivity.

Improvements in the design and in the waste management infrastructure can all concur at increasing the opportunity costs associated with the choice of not putting in place circular economy practices.

All of the above-mentioned flows of values need infrastructures that are efficient and smooth at the eyes of customers. To achieve igniting an actual change towards Circular Economy, Reverse Logistic Systems need to be put in place and adapted to any circular business model. In the next chapter, we will undergo an overview of what a Closed-loop supply Chain means.

1.5 Is the global economy mature for adopting a Circular Industrial Framework? Enablers and Barriers.

There are conditions that cannot be directly controlled by businesses but that are important drivers for the creation of an environment that foster circular economy practices such as the education – with the task to prepare future professionals for the new paradigm to come (Ellen MacArthur Foundation, 2012). While the pressure on the side of natural resources is rising from a procurement and financial point of view, incentives comes from certain factors - that we can name "enablers" – that are bound to facilitate whatever circular industrial model will be put in place in the immediate future. Scaling small projects up, being accepted at large on the consumer side, reducing the costs of operating the things up. Enablers will be divided in three categories: Technological advancements and intelligent assets, Consumer preferences and sociodemographic trends, Governments awareness and innovative policies.

After those three paragraphs about enablers of Circular Economy, we will be having a review on the principal barriers embedded in our socio-economic and technological context.

1.5.1 Technological advancements and intelligent asset

Technology has and will have a crucial role in this transition toward circular economy. The degree of coordination and information that the circular industrial model entails might have scared us the last century, when the framework was initially theorised. The efforts needed both to coordinate a reverse logistics to close the loop and assess the condition of a product or the performance of its general architecture vs. the performance of its single components meant the possibility of putting it in practice just to a limited scope of industries. Today the technology is so advanced we keep embedding it in a variety of items we interact with in our lives. "Internet of Things" (IoT) might be the new frontier of the digitalization of the businesses and – especially – our lives (Deloitte, 2014). For IoT we mean a network of physical objects, systems and processes that perform an exchange of information through internet. While IoT is composed by "Intelligent Assets", not necessarily all intelligent assets can be clustered as IoT items

since there are assets that are able to sense, keep track and send information about their status or their immediate surrounding – as an Intelligent Assets is – but others may not send information continuously or do not have a wireless connection to communicate it.

As Ellen McArthur Foundation outlined in its 2016 report ², "both IoT and the circular economy are about exploring connections and feedbacks" (p. 30). An interplay between them might be the key to unlock circular economy on an extensive level. Below a matrix that intertwines the value drivers of circular economy with the value drivers of the intelligent assets (Figure 1.5). Intelligent assets can alone solve many challenges presented by pragmatic application of circular economy practices (Ellen MacArthr Foundation, 2016) but can, in addition, address and solve key informational challenges with just the incredible mole of data they continuously spill.

Reverse logistics, essential to close the loop, need intelligent assets as key enablers to gain extensive strategic information (Ellen MacArthr Foundation, 2016) regarding:

- The location of the asset: the position of an asset needs to be tracked either continuously or discretely (through periodic connection or through data-collector checkpoints) in order to efficiently organise from a logistic and resources point of view any activity required to put the service in place. For business models that entail mobile and valuable assets that have to be deployed to reach multiple locations this is particularly important: intelligent assets can help those businesses to improve their operational performance by balancing resource utilisation (Deloitte, 2014). Data can be extracted in order to enhance the planning of the reverse logistic by knowing the usage path or also the behaviour of secondary market users to plan reuse activities
- <u>The conditions of the asset:</u> it is essential for what we have defined a "functional service economy" to have punctual information about the conditions of an item and at the same time to have a growing database with historical and trending

² Ellen McArthur Foundation; Intelligent Assets: Unlocking the circular economy potential; McKinsey, 2016. Available at: <u>https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Int</u> elligent_Assets_080216.pdf

information about the usage and wear patterns to better plan the operations from a logistic and financial point of view (Ellen MacArthr Foundation, 2016). Before the diffusion of intelligent assets and their condition-based reporting of performance and status of the items, maintenance could be triggered just by measures that were external to the item itself. "Preventative maintenance" could be triggered by planned time, weather/temperature/usage-based checkpoints. The actual condition of the asset – especially if technological – could be known more by "asking" it or by manually/remotely access it. Intelligent assets make it possible for users and owners/suppliers to trigger - based on established technical and commercial Key Performance Indicators and Service Level Agreements – condition-based maintenance, repair, decommissioning or change of use patterns (Crosskey, 2015). "Predictive maintenance" means knowing about a disruption or a malfunctioning even before it will occur: if the information is not precise from technological pint of view it will be completed by the predictive power of the data collected by the intelligent asset. In the age of perfect information and traceability about components and supply chains behind them, IoT make it possible to instantly update what is called "product passport" and the information about material composition and its potential change - e.g. due to weather conditions (Ellen MacArthr Foundation, 2016).

The availability of the Asset: the asset's availability is an extensive measure not only about whether an asset is idle or not but regards also the supply/demand dynamics regarding the whole chain of actions and interdependencies connected to its access and usage (Deloitte, 2014; Ellen McArthur Foundation, 2016).

A key decision for companies appears to be identify their partners within the circular economy systems, especially with respect to the interoperability of their intelligent asset environment, and then take decisions about whether they want to join a partner platform or embrace the investments in order to develop one on their own (Ellen MacArthr Foundation, 2016).

	INTELLIGENT ASSET VALUE DRIVERS				
CIRCULAR ECONOMY VALUE DRIVERS	Knowledge of the location of the asset	Knowledge of the condition of the asset	Knowledge of the availability of the asset		
Extending the use cycle length of an asset	 Guided replacement service of broken component to extend asset use cycle Optimised route planning to avoid vehicle wear 	 Predictive maintenance and replacement of failing components prior to asset failure Changed use patterns to minimise wear 	 Improved product design from granular usage information Optimised sizing, supply, and maintenance in energy systems from detailed use patterns 		
Increasing utilisation of an asset or resource	 Route planning to reduce driving time and improve utilisation rate Swift localisation of shared assets 	 Minimised downtime through to predictive maintenance Precise use of input factors (e.g. fertiliser & pesticide) in agriculture 	 Automated connection of available, shared asset with next user Transparency of available space (e.g. parking) to reduce waste (e.g. congestion) 		
Looping/ cascading an asset through additional use cycles	 Enhanced reverse logistics planning Automated localisation of durable goods and materials on secondary markets 	 Predictive and effective remanufacturing Accurate asset valuation by comparison with other assets Accurate decision- making for future loops (e.g. reman vs. recycle) 	 Improved recovery and reuse / repurposing of assets that are no longer in use Digital marketplace for locally supplied secondary materials 		
Regeneration of natural capital	 Automated distribution system of biological nutrients Automated location tracking of natural capital, such as fish stocks or endangered animals 	 Immediate identification of signs of land degradation Automated condition assessment, such as fish shoal size, forest productivity, or coral reef health 			

Figure 1.4 Interactions of circular Economy and Intelligent Asset value drivers with the relevant opportunities of value creation ; Ellen McArthur Foundation (2016) ; Intelligent Assets: Unlocking the Circular Economy Potential

1.5.2 Consumer preferences and socio-demographic trends: the "Sharing Economy" and its implications for the circular economy

Today's users are feeding up trends that goes in the direction of a preference of access over ownership. It is our supposition that young and urban consumers, especially, are driving the dominant economic model towards a new equilibrium that could be more advantageous to tackle the linear system down. Collaborative use models, with the whole set of unprecedented interactions between users, manufacturers and retailers are the main characteristics of this decade's trend called "Sharing Economy". The principle is maximising the utility of assets through contractual formulas such as renting, swapping, bartering and simply giving. The whole thing has been found itself facilitated and strongly scaled up thanks to the technological advancements that make it possible to take advantage of easy-to-access horizontal/collaborative platforms, feedback systems and trackability of the goods/services. Business models connected with the concept of Sharing Economy can create what have been called "Peer-to-Peer" (P2P) markets: a decentralized market model where the suppliers own both the means of the production and the finished product. On the other hand, the consumer consumes just a portion of the performance/time/utility of the asset without ever getting ownership of it. The object of P2P markets is incredibly various and in continuous evolution as this framework keeps gaining traction in the world: space, skills, assets of whatever nature and even time.

Sharing Economy can be considered a cultural before than a market and industry change. Thanks to it, ownership barriers have become blurred and the social, economic and environmental – either potential or effective – value of underutilised access can be therefore unlocked (Botsman & Rogers, 2010).

The huge variety of business models can – forcibly – be collected under three categories:

 Redistributive business models: enablers - such as Ebay, Facebook Market or Craiglist – reallocate goods or services that are no longer needed by an owner or by the temporal time-spatial condition. Here that we have the rise of secondary markets and reuse that do not absolutely go in just one direction: e.g. from industrialised to developing countries.

- Product-as-a-service systems: members or users can access the benefits of using an asset without owning it (Carsharing, P2P households rentals, musical equipment etc.). The members do not need to actually pay but, sometimes, forms of swapping, bartering, compensation or the usage of forms of payment from nt conventional currencies that gain value inside a community are well known and spreading.
- Collaborative lifestyle platforms: assets such as time, skills, financial resources, experience, space, company or whatever more or less intangible item can be shared and exchanged as long as there is people that perceive value in it.

The principles that are fundamental for them to work efficiently are: trust between the strangers, a belief in a higher interest for a sound management of the common resources, the existence of underused capacity and the creation of a critical number of users/consumers, retailers, manufacturers and, generally, members of a community.

If Sharing Economy operates at a systemic and collaborative level, its cultural effects can just be beneficial for the rise and acceptance of circular economy practices. Where technologies make it possible for retailers/manufacturers to extract more value without increasing their assets, where customers become active members of a community whose they recognise the value that can be obtained through collaborating, where active behaviour can be compensated with non-financial rewards within the same systems of goods/services/value, what it has been doing is a step towards Circular practices.

Sharing economy has contributed to tackle the cultural gap given by the figure of an active consumer that – following the rules of a centralised platform serving a decentralised community – take advantage of simpler reverse logistics to, for example, handle back its items or share the general architecture of an item while retaining an exclusive access to components that fit its exigencies.

Linking sharing economy to Stahel's "functional service economy" is temporally hazardous but conceptually easy. This new consumers' trends will make the people used to use and respect what they do not directly own.

1.5.3 Governments awareness and innovative policies

Awareness among the policy-makers have surely rose in the last 10 years. The environmental and economic alarms are shaping – more or less urgently – the agendas around the globe. We have already mentioned the "Ecodesign Directive" (2009/125/EC) with respect to the design of energy-related products. Moreover, still on a European level, there has been the approval of a "Waste Framework Directive" (2008/98/EC)³, trying to establish common and clear assumption with respect to waste managements' parameters and definitions. Apart from the focus on human health and environmental harm, the directive went in the direction of establishing waste management "hierarchies" (Fig 1.6).



Figure 1.5 Hierarchies in Waste Management according to the European "Waste Frmework Directive" 2009/98/EC; Extracted in: http://ec.europa.eu/environment/waste/framework/

³ https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

Within the same directive, we can find the introduction of concepts such as "Extended producer responsibility" and "Polluter pays principle" that can be considered as naturally legitimate as innovative.

In 2012, the European Commission issued the "Manifesto for a resource-efficient Europe"⁴. In the first line, there is a clear declaration of intents in that direction:

"In a world with growing pressures on resources and the environment, the EU has no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy. Our future jobs and competitiveness, as a major importer of resources, are dependent on our ability to get more added value, and achieve overall decoupling, through a systemic change in the use and recovery of resources in the economy. "

Circular Economy is claimed to be a "path out of the current crisis towards a reindustrialisation of the European economy on the basis of resource-efficient growth that will last". The commission called on business and civil society leaders to achieve a "circular, resource-efficient and resilient economy" through:

- 1. Encouraging innovation and incentivate public and private investments into resource efficiency
- 2. Adopt smart regulation and standards that reward the "front-runners" and take into account the social and environmental implications of the actions
- 3. Abolish harmful subsidies and other tax-breaks that keep incentivating obsolete practices
- 4. Promote circular product and service design that have lower impact at their lifecycles and that are recyclable until the moment in which they can be progressively taken out of the market when performance criteria are not met.
- 5. Use the advancements of behavioural economics and information technology to inspire and incentivate consumers into sustainable lifestyles

⁴ Manifesto For A Resoure-Efficient Europe; European Commission; Brussels, 17 December 2012; Available at: http://europa.eu/rapid/press-release_MEMO-12-989_en.htm

Three years later, the commission communicated to the European institution its "Closing the loop – an EU action plan for the Circular Economy" ⁵: an ambitious set of measures, actions and targets covering the whole life-cycle, from production to post-consumption waste, without leaving aside the secondary market for raw materials.

⁵ European Commission; Closing the loop - An EU action plan for the Circular Economy; Brussels, 02/12/2015; Available at: <u>https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614</u>

1.5.4 Principal Barriers for Circular Economy

When it comes to barriers to the Circular economy, many interview-based studies have clustered the up into various cathegories: cultural, technological, market and regulatory (van Eijk, 2015; Kirchherr, et al., 2017; de Jesus & Mendonça, 2018) but also financial, structural and operational (Ritzén & Sandström, 2017); Interrelatedness between barriers is structural.

Below an overview of the barriers that are perceived as the most incisive obstacles for adopting CE.

- Cultural barriers: in the study sponsored by Deloitte and Utrecht University, almost half of the respondents from the business world mentioned the lack of consumer interest and awareness, company culture and the cultural lock-in of operating within a linear industrial scheme as the main cultural barriers (Kirchherr, et al., 2017). Moreover, many respondents mentioned the volatility of consumer preferences and the contradiction with the principle of increasing the utilisation of a product over time. Another key factor here, is the complaints of some interviewees about the fact that CE keeps being discussed inside CSR/Environmental departments with the more influential ones, like finance or operations, being skeptical and reluctant (Kirchherr, et al., 2017).
- Market Barriers: many interviewees addressed the low virgin material prices e.g. of plastics whose price of the fossil ones are much lower of the bio-based or recycled one. It is not a matter of prices per se, but a matter of prices with respect to the circular alternative. This does not hold for materials such as many metals that can sustain many recycling stages without being downcycled. 40% of the respondents have mentioned the high upfront investments needed. Here the solution could be the rise of collaborative logistic platforms. Need for standardisation and therefore collaborative behaviours between players of the same industry has also been addressed as a pressing barrier to CE (Kirchherr, et al., 2017).
- Technological barriers: though many concerns about consumer data protection have been recently addressed with measures like the European General Data Protection Regulation (GPR), data security and trust are essential in a system that would require almost full informative potential from the players and the items involved in it. A huge theme with respect to intelligent asset is the need of interoperability of the IoT networks. It has been estimated that 40% of the value creation potential could be unlocked only through full digital ecosystem in which data sharing happens between assets and network especially from different players (McKinsey & Company, 2015). If many IoT systems have been designed in closed environments where everything was perfectly connected, here is that the reality would present a multitude of different devices and network created by different manufacturers (IBM, 2015). Companies, in order to improve their operating efficiencies and analytics technologies would definitely benefit from developing horizontally, in the direction of a commonly connected informative infrastructure, rather than push in the direction of creating vertical stacks of "independent" integrated products (Groopman, 2014).
- Attitude and knowledge: even before the lack of a real culture about CE, what emerges is an inertia towards considering new business models or even the whole sustainability theme as a strategic issue. Those factors combined with risk aversion make the choice of, for example, switching to a service provider scheme hard to be embraced (Ritzén & Sandström, 2017).

2 Reverse Logistics and Looping Supply Chains: an overview

If global legislation changes have spread the light over the activities connected with Reverse Logistics and Closed-Loop Supply Chain (CLSC), some manufacturers slowly started to recognise it as an opportunity before a cost-minimisation approach or a legislative imposition (Guide & Van Wassenhove, 2009). That is why managers who consider it just an environmental initiative to fill up some Corporate Responsibility Report should update their vision and thinking. Some modern firms that started to use CLSCs as a competitive strategy gain benefits like, among others, higher profitability and control over their product's entire lifecycles (Abbey & Guide, 2017). One of the most evident drivers for adopting CLSC strategies is the growing market for multiple lifecycle products – such as the remanufactured ones – estimated to be USD 100 billion in 2017 in US by the international trade commission⁶.

⁶ International Trade Commission (USITC) report on remanufactured goods. See USITC 2012. Remanufactured goods: an overview of the US and global industries, markets, and trade. Public report, U.S. International Trade Commission accessible at http://www.usitc.gov/publications/332/pub4356.pdf.

2.1 The basic principles underlying a Closed-loop Supply Chain

Conversely to the conventional forward approach to Logistics and – especially – supply chain, Reverse Logistics is the process of implementing and controlling the cost effective and efficient flow of raw materials, finished goods and information from either the costumer itself or the point of consumption to the point of origin, being the manufacturer or the retailer, with the aim of minimising the losses of value by recapturing it (Rogers & Tibben-Lembke, 1998). The result of joining a classical forward supply chain with a reverse one creates what has been many times evocated as "Closed Loop". One of the first illustration of a closed loop can be attributed to Beamon (1999), which had also imagined an evaluation stage where decisions on the products' destination should have been made. A more recent elaboration, as shown in the figure below, has been made by Chopra and Meindl (2010).



Figure 2.1 A basic overview of a Closed-Loop supply chain that joins Forward and Reverse Logistics. It appears the critical importance of a "central brain" – in this case is called a return processor – that processes the returns and judges their conditions and destinations along the various possibilities that increases their value yield over time. This is an adaptation from a model conceived by Chopra and Meindl (2010).

At the very core of a CLSC chain strategy there is the exigency, of variously built business models, of achieving some form of reuse or reclamation of either products or materials. It incorporates different aspects of a Reverse Logistics approach, such as design, control and operation of a system with, usually, the aim of maximising value creation and exploiting the residual value over the lifecycle of a product (Abbey & Guide, 2017). This exploitation is performed through dynamic recoveries of value over time from the chain's output: returns. Therefore, reverse logistics start from the end users and it coincides with the beginning of a management of the End-Of-Life (EoL) of the product phase. Different decisions may be taken regarding the objective of Reverse Logistics, from recycling, to remanufacturing, repairing and – eventually – disposing of some parts/components.

If CLSC intervenes at the EoL stage, a first life cycle must be effectively ended by accompanying the product towards a reuse market. A product is returned for a range of reasons among which we can outline two extremes (Abbey & Guide, 2017):

- End-of-use products where the utility or the residual performance potential of the item is over or almost so – are typical in B2B markets with large industrial machineries and equipment, that have considerably experienced an extensive and intensive use
- Convenience returns or "false failure" are typical of consumer products and are the consequence of a - sometimes arbitrary - decision that a product simply does not suit a consumer's needs, desires or even status quo anymore. The likelihood that some returns are false failures vary from industry to industry. In the consumer electronics industry there have been 80% experienced false failures for inkjet printers as well as 2% power drills (Ferguson, Guide, & Souza, Supply chain coordination for false failure returns, 2007).

2.1.1 Activities, risks and flows within a Closed-Loop Supply Chain

A high-level view of a CLCS system can make it possible to cluster the activities into three main categories: front-end, engine and back-end activities (Abbey & Guide, 2017).

- Front-end activities refer to Product Acquisition Management aimed at collecting back the returned products. The first step of physically acquire the returned products can become operationally challenging and costly in case that the products are either difficult to collect and/or geographically dispersed. With respect to returned products that are geographically dispersed, Location of the collection facilities appear to be the most critical factor of success for a Reverse Logistic system (El Korchi & Millet, 2011).
- The "Engine" activities take place once the returns are collected. The Engine allow the returns to be processed into a reuse condition through, for example, a remanufacturing/refurbishing process. The returns, before being processed, need to undergo a technical feasibility analysis to be identified in the constraints that design, material composition or market acceptability put in place and the related operational issues entailed. Information and predictive models can somehow estimate the quality of the of the materials/components contained into returns. The grading of the quality of the product cores that are acquired in the front-end processes of CLSCs can have a considerable impact on the operational and economic performance (Ferguson M., Guide, Koca, & Souza, 2009) but, as we will also see in the next paragraph, informational gap could be filled out by intelligent assets and predictive maintenance as well as product passports. At the end of the "engine" stage the products have been renewed and brought back to marketable conditions.
- Back-end activities entail marketing the product again for another lifecycle. The nature of the demand of reused products started to draw some attention of the researchers in the very last years. The back-end activities, being the ones that should actually gain the returns on the whole CLCS operations are what scares many manufacturers: consumer acceptance, brand consequences and the risk of cannibalization that, sometimes, is so strong to delay or even prevent the

remanufactured products to be marketed (Atasu, Guide, Jr., & Van Vassenhove, 2010). In 2015, an extensive study on market reactions to remanufactured products highlighted how there is a 20/30% of consumers that would always go for new products, while the other potential segment should be reassured about the quality of the remanufactured components and be priced with a discount that strategically do not exceeds 40% as higher discount would decrease the perceived/expected quality of the products (Abbey, Meloy, Guide Jr., & Blackburn, 2015).

In addition, it must be taken into account the marginal value of time pressure that a product/component may have with respect to its destination market. The technology sector faces a higher marginal value of time as products are depreciated by changing market needs/requirements and the pace of innovation. Therefore, the cost of performing activities such as acquiring, testing, inspecting and returning the product to the market is strongly correlated with the quickness and efficiency of such operational efforts. It has been observed how, in a fast-moving consumer electronic sectors as the HP's inkjet printers, even one day of delay has remarkable effects on the returns of the whole CLSC operations (Guide, Souza, Van Wassenhove, & Blackburn, 2006).

As the range of choices with their related degrees of constraints is wide, it is critical for managers to understand those and how they vary among industries. The figure below (figure 1.5) displays a general representation of the various flows that take place at a product, component and material level. As the returns are collected at the beginning, activities appear hierarchized based on their value potential through multiple lifecycle. It is the operational translation of the above-mentioned concept of "cascade". Physical, chemical and economic value is retrieved the if products or component reprocessing, through refurbishing or remanufacturing, are performed before considering a material reprocessing, a process that consist in the material recovery through recycling activities and even requires more energy.



Figure 2.2 Closed Loop Supply Chain flows and function (Abbey & Guide, 2017)

In addition, as shown in the above figure, it appears physically inevitable to have some kind of end-of-life waste streams. Some products, components or, lastly, materials have a limited or even single number of life cycles. It is a task of major importance for supply chain managers to identify channels for their waste streams that can translate into profitable opportunities.

As a one-size-fits all approach is not reasonable for such complex activities, the sections will try to match a firm's CLSC strategy with the nature of its market along the dimension of product design and core competencies.

2.2 Product Design and Closed-loop Supply Chain as a Core Competency: strategic implications

Designing a product for multiple lifecycles has positive effects but, especially in the case of consumer technology industry, market pressures and, as mentioned before, arginal value of time must be taken into account. Therefore, some firms have adapted their design strategies to the nature of their industries' competitive structures. On the other hand, as an industry gets more mature and the pace of innovation slows down, is where a firm should start getting to now and considering putting in place CLSC strategies to increase profit opportunities (Abbey & Guide, 2017).

Organising these aspects along two dimensions, namely design and core competencies in reusing or extracting back the value from the market, we have the matrix showed below as a result (Figure 1.6).

Most of the degree of recoverability that can be achieved both at a product and component level is influenced by product design. At the material level, integration between components is a key major barrier when it comes to recover heavy metals from consumer electronics such as smartphones or laptops. Consequently, the influence of product design spreads towards product acquisition management and both engine and back-end activities. Another insight is that product acquisition management and, generally, the front-end activities of a CLSC, requires decisions on whether to put in place reverse logistics and transportation networks in-house or outsourced, based on the degree of core



Figure 2.3 Design of product lifecycles and reusing strategies for product reusing as a core competency within a CLSC environment

competences that a firm possess or could be able to achieve. Moreover, the operational requirements of a reuse process and especially the choice of its recovery level – being at product, component or material level – requires important investments in remanufacturing capabilities with respect to both capital and human resources (Abbey & Guide, 2017). The final implication is the strategy to put in place on the market, where leasing can imply a major control over the multiple lifecycles.

Now we will review the operational and managerial implications of each quadrant.

2.2.1 Quality, Durability and Maintainability strategy

Here, original manufacturers focus on quality, reliability and maintainability. Examples may be the vehicle, airline and train industries where, in many cases, the post-sale support is limited and fleets/assets are renewed after long time spans. With a "robust design", having the asset lifespan maximised makes those items similar to other industries that, through multiple lifecycles, exploit the prolonged post-sale control of the assets by, for example, retaining the ownership. Business lines that are associable with this quadrant

have no core competency nor interest in reacquiring the assets after a sale has already taken place. The immediate downside, as the original manufacturers completely lack in asset control, is the empty space left to third-party industries to grow and seize the remanufacturing opportunity as the profit potential have been ceded to them. This is what happened to the airplane manufacturers which left the whole industry of remanufactured core components to third-party entrants. Delta and Lufthansa – generating cost savings and profits through multiple lifecycles activities of both theirs' and others' equipment - have been permitted to specialise in testing, inspecting and processing used components and gain market presence, building a competitive advantage that appeared prohibitive to original manufacturers⁷. As the remanufacturers specialise, they are able in the future to even sell their commercial refurbishment services, as it happened with Lufthansa⁸. In a few words, firms that operate within this quadrant partially or totally renounce in gaining market presence in the multiple lifecycle product market but do not need to bear investments in CLSC and capital remanufacturing systems.

2.2.2 Multiple Lifecycles Strategy

Through appropriate design strategies, the manufacturer focuses on generating as many product lifecycles as possible in order to maximise the total lifecycles profits. In order to be captured, strong vertical integration is needed at the initial sale and reacquisition stages. If a proper vertical integration is not present, design strategies will end up favouring third-party remanufacturers that are willing to extract the value from the opportunities of generating multiple lifecycles. Therefore, investments are need in Reverse Logistics systems and in the remanufacturing facilities, which will be eased in testing, inspecting and processing activities at the design stage. Xerox differentiate between customer types based on performance/price dimensions and offer packages of partially remanufactured products as well as new ones. The high performance and lower price of the remanufactured machines are one of Xerox's main competitive advantages.

⁷ Carry, Susan. 2012. "Delta Flies New Route to Profi ts: Older Jets," The Wall Street Journal November 16, 2012.

⁸Lufthansa Technik AG: business offer and refurbishment related services. Accessed on August 20, 2018, at: http://www.lufthansagroup.com/en/company/business-segments/maintenance-repair-overhaul.html

2.2.3 Single Lifecycle strategy

Consumer tastes change rapidly in fast moving industries such as the consumer electronics, making the act of extracting value from returned product way more difficult. As a consequence, the idea of conceiving multiple lifecycles designs has been put aside, with a strong focus on maximising profits through resource efficient designs and manufacturing systems. In addition, due to warranty strategies, the key is often minimising the return of products in order to minimise the losses connected with it. The side effect of this has been, especially in the consumer electronic industry, a monstrous global waste stream - we will look at it in the second chapter. As already mentioned, recent studies have highlighted how for many products there are considerable slices of the market who hold absolutely no interest to buy multiple lifecycle products, while reluctancy on internal components/materials can be tackled down with appropriate communication and assurances regarding the quality and, also, the hygiene (Abbey, Meloy, Guide Jr., & Blackburn, 2015). Firms operating with single lifecycles design strategies will need to conceive models to increase the appeal of refurbished products and investigate the market acceptance of a refurbishment done at a component level, when no performance indicators are modified. Those firms will likely find themselves operating reverse logistics and therefore upstreaming relevant design strategies to do so, to perform reuse strategies at least at the material level.

2.2.4 Third-party Reuse

ReCellular's business idea was ignited by Motorola proclaiming that no business could be put in place by remanufacturing its products/components. The third-party re-use is a direct consequence of the fact that an original equipment manufacturer considers product/component/material level reuse as a non-core competence. When this happens at a material level, the manufacturer has simply ceded a market for which it lacks interest or competence/capability. When this happens at a product level, by letting third-parties free to remanufacture, the original manufacturer has created all the precedents for creating/attracting a competitor in its own market space and that uses its own products/components. The manufacturers often complain that:

- Reacquisition appears as too difficult or costly
- Reverse Logistics systems are hard to manage
- Big Investments in remanufacturing activities
- Complex inspecting and testing activities
- Fear of cannibalization

While these fears prevent many original equipment manufacturers from putting in place CLSCs strategies, the third-party manufacturers keep entering a market that makes billions of profits each year. On the downside, third-party remanufacturers usually lack the access to the returns, the market power and the forward supply chain – with the promotion and distribution channel - the original manufacturers are endowed with.

2.3 Third-party vs. Original remanufactured products: a behavioural analysis of consumer perceived value

A twisting and at the same time fascinating research has been conducted by Agrawal et. al (2015) on the effects of the presents of remanufactured products on consumers' perception using a behavioural approach. The perceived value of new products in the presence of a remanufactured alternative proposed by the same original manufacturer had negative effects on some products, by decreasing their perceived value by 8%, but also positive effects on others, which increased their perceived value by 7%. The researchers assumed that this could have been correlated with the de-valued product being high-end and characterised by hedonic and/or emotional attributes, being it an Apple MP2 player, while the over-valued one being perceived as a low-end and utilitarian item, being a Sansa or HP mp3. On the other hand, the research surprisingly suggested that the presence of third-party remanufactured products – not directly fro the original manufacturers – actually always bring to an increase in perceived value of the new products, no matter what the product category and the brand is. Based on these insights, some additional prescriptions should be given to manufacturers:

- It is important to investigate the effect of the presence of remanufactured products on the perceived value on the new one both in the case that the remanufacturing activities comes from in-house or outsourced activities
- If the remanufactured items coming from the original manufacturers have negative effects, still the original manufacturers could benefit from having remanufactured products under a different brand. This would mean outsourcing just the final sell of the remanufactured products.
- Original manufactuers can put in place measures to limit the negative effects on perceived value correlated with the presence of remanufactured products. For instance, both Apple and HP discriminate the customers that can actually access their remanufactured products. The former does it with respect to the distribution channel and the type of customer that uses the product, being that the sell take place only through internet. The latter discriminates geographically by selling only in separate secondary channels in Europe.

The presence of third-party remanufactured products together with a communication campaign that highlights the superior quality of the new products could strengthen the quality perception and therefore the value the customers would attribute to the new product. HP performed a marketing campaign to reinforce the perceived superiority of its new cartridges.

2.4 Corporate strategies and Reverse Logistics: Vertically integrated, Hybrid and Outsourced Closed-Loop Supply Chain strategies

As stated in the previous section, an Ideal CLSC requires the Reverse Logistics system to be vertically integrated together with a design strategy that aims at achieving multiple lifecycles products. The combination of these strategies can find its main barriers in terms of:

- Technical infeasibility: nature of the product and marginal value of time
- Financial infeasibility: investments in reverse logistics, remanufacturing facilities and back-end activities to market the output needs important investments to be born
- Existence of a market for shorter lifecycle products.

Within this view, third party involvement appear to be a strategic choice that can be both profitable and functional, especially when core-competencies does not make the original manufacturer able to seize the proper amount of residual value. Therefore, the original manufacturer is left with a choice on the nature of its Reverse Logistics system, ranging from a pure outsourced CLSC to a pure vertically integrated CLSC approach, where, in the middle, is compromised a wide range of hybrid possibilities (Abbey & Guide, 2017). Back to Xerox example, limited ownership over the reverse logistic system is retained, while the transportation towards the remanufacturing facilities is almost completely outsourced.

The primary differences in the corporate strategies with respect to CLSC are the intensity and complexity of remanufacturing operations. Of course, especially in highly technological industries, there will be some components which will be coming from an external entity no matter what the choice on CLSC ownership will be. It must be recalled that the original manufacturers always play a role in restricting the access to some forms of remanufacturing market out of its products/components to unauthorised third parties. In order to have the differences clear and remarkable, vertically integrated and outsourced CLSC strategies will be firstly reviewed below

2.4.1 Vertically integrated CLSC Strategies

Vertically integrated CLSC strategies have the control as the main strategic objective but also the main source of organisational and managerial challenges. Following a proposed structure:

- 1. Products are drained through a product acquisition management
- 2. Testing, inspection and disposition at the different reuse levels are performed in-house. Eventual materials to be either recovered or disposed of will be rid of at this stage
- 3. The remaining sourced parts will be furtherly evaluated and the results will be compared with the production planning activities. Following either an eventual procurement order to fill the component needs for the remanufacturing batches or a further remanufacturing of the sourced parts, if their value is still recoupable at reasonable cost-time combinations.
- 4. Sourced parts, newly ordered components and remanufactured sourced parts will go through remanufacturing operations
- 5. Remarketing the items in order to exploit the additional lifecycles generated

There are problems that can surge if first place production and remanufacturing take place within the same institutional boundaries with respect to procurement, operations and marketing (Abbey & Guide, 2017). The first one regards the risk of loosing the optimal product quantities and relative prices/costs combinations. Bulk rate economies of scale with respect to activities such as procurement and transportation might be severely damaged. Take the case of a procurement division that, thanks to the CLSC activity receives an order from the remanufacturing division to decrease the order quantity for a certain component/material. Problems connected with such strategies could also arise, from an operations management point of view, by the physiological effect of an unstable level of production, with all the problems connected with the choice of the optimal scale of production. If on one hand the labour and equipment productivity and utilisation over a certain time span can improve, setting the

production plants to variable level can be a costly condition for their management. The last one regards the risks connected with the optimal quantities of allocation with respect to both new and remanufactured products as too much risks to cause cannibalization effects and too little risks to make the remanufacturing operations unjustified.

2.4.2 Outsourcing CLSC strategies

Outsourcing CLSC strategies, if purely applied, may generate chaos and profit losses. Following a proposed structure:

- 1. The product acquisition management is performed by a contracted thirdparty
- 2. The whole process of testing, inspecting, disposing and remanufacturing is performed following the predefined metrics and specification given by the contractor. Using not only the contractual obligation but also by imposing intellectual property barriers on components and design, if possessed
- 3. Remarketing activities and exploiting of the additional lifecycles

If forward supply chain – which comprises also the production stage - is outsourced, then the reverse one and reuse/remanufacturing operations will be outsourced as well. One of the reasons, apart from – again – a core competencies and management complexity point of views, is that old manufacturing facilities could reveal too costly if being used to perform remanufacturing ones alone. To express this concept, the Dell case – which was forced to outsource also its remanufacturing operations after having outsourced parts of its forward supply chain - will be outlined in the next sections. There are multiple complexities connected with a fully outsourced CLSC, making it rarely achieving as much profits as the vertically integrated or hybrid approaches strategies. The first downside of a fully outsourced strategy is the total or at least partial loss of precious insights on design flaws and the related improvement opportunities they entail. Solutions to make the designers access the returned products/components need to be formulated as having them not accessing those insights to garner feedback could be a big loss. From a contractual point of view, obligations for the parties – if not unique – gain considerable complexity as both forward and reverse contingencies that a CLSC entails must be contractually predicted and disciplined (Abbey & Guide, 2017). Therefore, the fact that contracted reverse logistics and especially reuse/remanufacturing partners usually are not endowed with great competencies in commercialising the products back to the market (Abbey & Guide, 2017).

2.4.3 Hybrid CLSC strategies

Hybrid CLSC strategies are what the majority of firms actually put in place. Being hybrid, a firm will choose the best match with its core competencies. The main strategic error a firm could make here is in the evaluation of the current core competences: those that a firm possesses and could be easily developed to generate additional profits and those which the firm would need to put in place CLSC strategies and that the firm still does not possess. Those errors could concretise in a firm dismissing a profit opportunity due to a current lack of a core competence that could be developed in-house. Moreover, design specifications should be retained in house in order to not lose the whole equilibrium in the CLSC system. Additional managerial themes at stake in such hybrid strategies regard intellectual property, pricing contracts and the loss of control over the CLSC system. The key activity in hybrid strategy is therefore the evaluation of internal competences together with the cost structure of CLSC strategies and the opportunity costs involved with leaving aside such activities. A firm may decide to, outsource the whole processing of the returns but retain in-house the remanufacturing and even the commercialisation of the high profit items to – for example – do not disperse know-how or to not affect the brand image.

2.4.4 Putting all together: choosing the right CLSC strategy

Again, with respect to CLSC strategies, there are no one-size-fits-all approaches. It must be noted how fully vertical approaches to CLSC are rare and small in absolute numbers (Abbey & Guide, 2017). As the products becomes more widely distributed and less expensive, the optimal lines between the right approaches blur and multiple trade-offs occur. In addition, as it has been highlighted many times, problems multiple up as the product has a short lifecycle on the market because of – for example – a high marginal value of time.

Putting all together, there are different decisional levers to be taken into account:

- Product design
- Business model
- Product reacquisition management
- Reverse logistics
- Testing, inspection and disposition processes
- Remanufacturing processes
- Remarketing the reused products, components or materials

As it can be seen in the below figure (Figure 1.7), the third parties may perform a role or managing some stages in many cases. The decision flow below-presented is in line with successful performance of dozens of companies along some decades of observation (Abbey & Guide, 2017).



PrAM stands for Product Acquisition Management |TID stands for Testing, Inspection and Disposition

Figure 2.4 A chain of decisions to be taken by managers to decide the CLSC strategy to put in place

One of the most interesting take-homes here is that, when a product design is robust and aims at multiple lifecycles, the decision between a product approach or a Product-as a service-approach, that is one of the main themes within the circular economy framework, have implication on the ownership structure of the firm. A firm that sells its products would be bettered off by putting in place a Product acquisition management and a reverse logistics which is outsourced. On the other hand, retaining the ownership of the item by just giving the access to users leaves to the firm some decision power regarding that following step.

The trend observed by Abbey and Guide (2017 is that on one hand, forward supply chain keeps being outsourced – in line with the overall tendency of many industries towards decentralisation, one of the consequences of Open innovation framework and the diffusion of the market for technology -, on the other hand, in-sourcing remanufacturing activities is being always more difficult. As mentioned before, once a forward supply chain and the related manufacturing activities are outsourced, usually also the remanufacturing ones follow the same path.

The key strategic take-home is that third parties' activities – or potential future ones – shall not be ignored, since other players could enter and compete the manufacturers in the very same market with or without their consensus. In that, Dell's strategy has been proved

to be superior since, even though all the reverse logistics has been outsourced, some kind of contractual control has been retained and, in turn, value has been extracted. The same cannot be said about the original manufacturers in the automotive industry. Third-party players have always retained a strong control over the automotive parts product acquisition market. As already mentioned in the case of airline sectors, this makes those players able to specialise and gain competitive advantage in the remanufacturing activities in terms of material flows and in activities such as testing, inspecting, determining the reuse level and especially gain market presence. Even though the original automotive part manufacturers complained with the third-party manufacturer about them "stealing" their components, no actual steps had been taken to gain or maintain a vertical control over their products after the initial sale was performed.

Because of these knowledge, scale and specialisation economies, it can be stated that, once an industry cedes control over remanufacturing activities and leave it free to be seized by third parties, regaining that control over again once the market has been recognised and it is growing can be difficult and costly (Abbey & Guide, 2017).

Even if investing resources in terms of capital, skilled labor and reverse logistic networks is beyond core competences, contracting up with third parties can prove valuable and prevent others unauthorized third parties from filling up - in the future - a business vacuum.

2.5 Outsourcing remanufacturing activities with innovation-based contractual schemes: the case of Dell and Genco ATC

Dell is a U.S.-based company operating in the ICT industry. In 2005 they had selected GENCO ATC as third-party partner to manage Dell's return and repair processes (Vitasek, Manrodt, & Ledyard, 2013). GENCO ATC was a large wholesaler of retail returns and surplus inventories, therefore a player in the Reverse Logistics field.

As the competitive pressure was raising, Dell initially decided to consolidate its whole sites into a single refurbishment center, ideated to take care of all the engine activities such as testing remanufacturing, repairing and refurbishing along all its product lines (desktop, notebooks, servers and storage systems). Ultimately, a decision towards a further outsourcing strategy was taken. Dell decided to sell its Lebanon facility – the one that had been chosen as central facility for its global reverse logistics activities – and also to transfer its employees to the service provider who would have ran that very same facility. In 2009 GENCO ATC won also this bid and acquired Dell's buildings, assets and people connected to reverse logistics activities in a three-year contract. Compared to the company's business-as-usual that well represented a long-term contract for a long-term strategy. Dell was used to re-negotiate out-sourcing contracts almost every year to have their partners compete each other in reducing their costs but that time – as tangible assets and human capital were involved – their third-party collaborators needed the high upfront investments required to access the partnership to be amortized along multiple years.

The contractual terms were articulated, with tons of billable items and one hundred of service level agreements. The initial contract was a transaction-based agreement where GENCO ATC was bearing the risks of meeting the target price per activity – therefore its costs – while maintaining the agreed service levels. All of it accompanied by penalties that get activated once a key performance objective is not met. Moreover, the contract involved time obligation regarding the transferred employees – wages and retention - and assets. In addition, Dell was continuously requiring GENCO ATC to invest in cost-reduction and service-enhancement innovation which, because of the relatively short-

term nature of their contractual agreement, was financially too risky. Returns on investments in innovation could have been rarely returned in such time span.

At the beginning of the third year of the contracts, Dell had decided to change approach towards GENCO ATC. It had been recognized the incentives to be not synced. GENCO ATC should have been provided with incentives to innovate that were consistent with Dell's willingness to achieve a transformation in its supply chain. Dell had fell in the trap of focusing too much on transactions and transaction costs, creating a transactional contract that was aiming at rewards and punishments regards the contractual activities alone. The contract main driver had been the cost-per-box and GENCO ATC had no incentive to think out of the box and getting out of its processing and refurbishing routines, but just achieve efficiency within the same system.

The pivot it was ideated by Dell was to shift the managerial focus from the cost-per-box towards the loss-per-box. The concept of loss per box was shifting the focus to profitability and margin in a collaborative environment between the two parties. How these two players could work together to maximize recovery and decrease the margin loss on Dell returned items globally through secondary markets exploitation, supply chain and reverse logistics intelligence and operational excellence?

Measures that were starting to be discussed regarding goals and business expansion opportunities. The collaboration scope had started to be enlarged to activities that were outside the limited scope of the first contract, the mere transaction of returned products for refurbished ones. Identifying activities that would have been better performed by the other party meant also providing additional revenue streams to GENCO ATC. For example, the design, mechanical and engineering insights GENCO ATC might have regarding a product could help Dell to better predict the failure rates or prevent an item from going through the whole global channel of returns but rather deliver on-site solutions.

2.5.1 Pricing Scheme

With respect to the pricing structure, there was the need to move away from a price-peractivity scheme and move to a pricing scheme that took into account both the reductions in loss-per-box and the overall profitability of Dell and GENCO ATC put together, for the sake of a mutually desired outcome. In addition, another key ratio used was to avoid a party to either being rewarded nor penalized for any activity or event outside its control. Putting it into practice meant providing GENCO ATC an industry average Return on Investment as an assurance against the fluctuation of activities out of its control – such as the volume and the variability of the returns. GENCO ATC would have earned higher that normal margins when achieving the agreed mutual desired outcomes. Above certain tresholds, financial benefits would have been shared with the contractor. Ultimately, it was interesting the fact that the contracted third party was assigned a shared value ratio whose main drivers were:

- GENCO ATC's ROI: a bigger share of financial surpluses starts being gained by Dell after GENCO has reached and exceeded its ROI
- Time: a larger share of financial benefits was given to GENCO initially and it would have decreased as time was passing. This would have made GENCO able to recoup investments more quickly and thus also give them the right incentive in investing in innovations towards the achievement of the agreed-upon mutually desired outcomes.

The results were successful. The partnership had generated US 1 million financial benefits for each party in just one semester. Moreover, the mutual strategy manged to achieve a 62% decrease in products that were heading towards recycling and so that were directed towards activities of higher profit potential.

The case has taught how outsourcing remanufacturing activities shall be a concerted effort towards a mutually desired outcomes rather than a mere transaction-based contract focused either on profits or cost reduction.

3. A circular industrial model for Consumer Electronics

While consumer electronic keeps becoming vital to the functioning of our societies and lives, the same devices keep being used for short time spans before being marked as not valuable or useful. By 2017, half of the world's population uses the internet and most of them will own more than one information and communication technology (ICT) device (Baldé, Forti, Kuher, & Stegmann, 2017).

Items such as smartphones, computers and wearable equipment, though composed by durable and valuable materials, are subject to relevant losses of value and resources because of the above-mentioned mainstream disposable practices (Ellen MacArthur Foundation, 2017).

From a product point of view, design strategies that aim at modularisation and standardisation can ease the adoption of circular practices. From a technological point of view, switch to a dematerialised and virtualised cloud computing infrastructure can decrease the demand on devices' performance, making them simple interfaces hat can therefore be used for longer due to a lower wearing.

From a costumer point of view, if the focus is shifted on the actual functionality of a device, distinctions between new and second-hand devices could be tackled down when their components are both new and used and/or remanufactured. In addition, consumer behaviours should be taken into account when it comes to make a device circulate as long as possible among different categories of users – "cutting edge"," function focused" and "emerging users" – and their relative budgets (Ellen MacArthur Foundation, 2017). Different utilities and performance requirements for different segments.

This downward movement regards both product and components that can "cascade"⁹ from high-end demanding costumers to lower performance applications before eventually entering a recycling stage where, again, the same ratio should be applied in formulating upcycling solutions before downcycling or energy recovery.

The chapter will start with a high-end view of the global waste streams and loss of values connected with the consumer electronics industry.

⁹ Cascading, as mentioned in chapter one, is the process of exhausting all higher-value products and services possibilities before performing recycling/energy recovery. The ratio is to maximise the resource effectiveness of products, components, materials.

3.1. Electrical and Electronic Equipment: Waste streams and Consumption trends

In this paragraph we will undergo an exploration of the key losses of value that the linear industrial model entails within the EEE industry.

By the term "Electronic waste" or "E-Waste", we refer all the items of electrical and electronic equipment (EEE) and its parts that have been discarded without conceiving any "cascade" activities that would further express their residual utility and/or value. The abbreviation used also by the European Union is WEEE, meaning "Waste Electrical and Electronic Equipment". WEEE comprehends almost any household or business item that contains electrical components with power or battery supply (Baldé, Forti, Kuher, & Stegmann, 2017). WEEEs are currently clustered in six categories:

- 1. Temperature exchange equipment: refrigerators, air conditioners, heat pumps
- 2. Screens and monitors: TVs, monitors, laptops and tablets
- 3. Lamps and LED
- 4. Large equipment: household large electric appliances, printing machines and photovoltaic panels
- Small Equipment: household smaller electric appliances, electronic toys and tools, small professional devices
- 6. Small IT and telecommunication equipment: mobile phones, GPSs, personal computers, printers, telephones

Each category has different profiles in terms of life-cycles, generated waste streams as well as potential environmental and health impacts. In parallel, the logistic and infrastructures to be organised for their collection and/or recycling vary for each category.

EEE's diffusion worldwide is increasing. The global percentage of Households with either a computer of an internet access is around 50% in 2017, doubling the values of 2007. Moreover, if the average consumption of EEE has slowed down in richer countries,

it reaches high values (e.g. from 13% up to 23%) in emerging countries (Baldé, Forti, Kuher, & Stegmann, 2017). Some technologies became obsolete, often substituted by multi-functional devices such as personal computers and mobile phone.

Other trends are causing the e-waste generation according to the Global E-Waste Monitor¹⁰ (2017) are:

- Multiple device ownership: e.g. between 2012 and 2015 the USA citizens that owned simultaneously a smartphone, a tablet and a computer had doubled to 36%
- Overall tendency of the market to electrify equipment that were once nonelectrical
- The growth of cloud computing decreases the devices demand on one hand, as multiple services can be accessed from a single device, but it increases the e-waste through the increasing number of data centres and their depletion over time.
- Shorter replacement cycles: in the smartphone industry the lifecycle does not give an idea of the actual end of life of the devices but it is more correlated with the pace of innovation. That is why, as the pace of innovation slowed down, average lifecycle of smartphone is increasing in USA, China end the main EU countries, ranging between 20 and 22 months in 2016 (Guenveur, 2017). Subject to this phenomenon are also laptops, TV sets and other devices that are often replaced even if not broken or obsolete.

Recent data are appalling and display a huge 44.7 million tonnes of electronic waste globally in 2016, out of which 435 thousand tonnes were just mobile phones. The expected amount of e-waste per inhabitant is expected to increase to 6.8kg by 2021, while in 2014 was 1kg less. According to 2016 data, just 20% of that huge amount of e-waste is documented to be collected and properly recycled globally (Figure 2.1). Out of the 4 huge global blocks, Europe appears to have the highest performance of WEEE which is documented to be collected and recycled (35%). Moreover 76% of them, as displayed in

¹⁰ Referenced on the bibliography as (Baldé, Forti, Kuher, & Stegmann, 2017). Available at: <u>https://collections.unu.edu/eserv/UNU:6341/Global-E-</u>waste Monitor 2017 electronic single pages .pdf

the figure, are not documented and therefore likely to be dumped, traded or treated under substandard and inefficient conditions (Baldé, Forti, Kuher, & Stegmann, 2017).



Figure 3.1 Aggregated global data on collection and recycling rates of E-waste in 2016. (Baldé, Forti, Kuher, & Stegmann, 2017)

In addition, we need to mention how satisfying the demand for resources connected to the electrical and electronic equipment (EEE) has been linked with dangerous working condition: e.g. cobalt mining in central Africa using child labour 11 – named "black gold", being a key component in smartphone lithium-ion batteries.

¹¹ Financial Times, 2017. Amnesty warns on use of child labour in cobalt mining. https://www.ft.com/content/ bec64762-c923-11e7-ab18-7a9fb7d6163e

3.1.1 The value of global WEEE streams

A large variety of materials and plastics are contained in EEE. Many of the 60 elements of the periodic table that can be found within conventional EEE could be technically recoverable but there are important constraints in terms of time, cost and logistic (Baldé, Forti, Kuher, & Stegmann, 2017). Precious metals contained in E-waste are, for example, gold, silver, copper, platinum and palladium.

Economically speaking we are witnessing a huge loss of value. In 2014, when the global e-waste generated was 3 million tonnes less (41.8 million tonnes) its intrinsic material value was estimated to be around EUR 48 billion (Baldé, Wang, & Huisman, 2015). 2016 value has risen to an estimated EUR 55 billion euro (Baldé, Forti, Kuher, & Stegmann, 2017), meaning that the average value per tonne has even increased: from 1148 to 1230 € per tonne, an increase of 7.15%. The table below displays an estimation of the global losses of value among the main materials identified in WEEE streams.

Material	Kilotons (kt)	Million €
Iron	16283	3582
Copper	2164	9,524
Aluminium	2472	3585
Silver	1,6	884
Gold	0,5	18840
Palladium	0,2	3369
Plastics	12230	15043

Table 3.2 Potential value of raw materials in e-waste in 2016, (BALDÉ, FORTI, KUHER, & STEGMANN, 2017)

3.1.2. Mobile phones and waste streams: some figures

Mobile phones have becme one key device in our modern society, as their ar bound to substitute many other terminals, becoming the interface of a complex, centralised and interconnected flow of information and computational power that happens in clouds. As their substitution rate increases, some pressure is being put on the structure and the functioning of the industry as the used devices are badly disposed and precious materials terminate their economic utility often in landscapes.

The value alone of the wasted mobile phones was estimated to be 9.4€bln in 2016 (Baldé, Forti, Kuher, & Stegmann, 2017). As a study revealed, mobile phones could become an important secondary source for precious metals like silver, gold and other metals with industrial aplications such as Copper, Nickel and Zinc.

Some studies have estimated the recycling potential of the waste streams coming from mobile phones alone. Chancerel et al. have estimated that, out of one tonne of wasted mobile phones, it could be recouped 3573 g of silver, 368g of gold and 287 g of Palladium (Chancerel, Meskers, Hagel, & Rotter, 2009). At actual prices¹² we would be talking about more than EUR 24'000 just for these three metals and assuming 2009 recycling technological potential.

Within a mobile phone archtecture, it has been identified that the the components that would be more adapt to be subjects to circular practices would be the camera, the display and also the battery and the charger; being the most valuable parts and easiest to disassemble (Ellen MacArthur Foundation, 2012). But others have highlighted how printed wire boards (PWBs) – that could be considered the control center of the devices – could be another important stream of hige value coming from recycling precious materials. It has been predicted that, assuming a 100% recycling rate, 9.01 tonnes of Gold and 14.1 tonnes of Silver could be recovered just in China from wasted mobile phones (Tan, et al., 2017). Another study (Hagelüken, 2008) estimated that, within 1000 units of mobile phones there are:

- 250 tonnes of Silver
- 25 tonnes of Gold
- 9000 tonnes of Copper

¹² World Bank Commodities Price Indicies; April 24, 2018. Average USD/EUR Exchange: European Central Bank. Accessed on 01/09/2018. Average exchange equaled to 1.1904

- 9 tonnes of Palladdium
- Other precious metals that are considered scarce (Mo, Zn) or Moderately scarce (Cd, Cr, Cu, Fe, Ni, Pb and Sn)

How should all this value be captured? What would, operationally, need any circular practice in order to be put in place? An adequate reverse logistic system to close the loop and ignite beneficial cascades to increase the resources effectiveness over time. We will explore it in the next sections.

3.2 Taking the Electronic Industry Away from the Linear Industrial Model

Circular Economy represents a vision and a workable path forward to rethink the system of the EEE industry and take it away from the Linear Industrial Model of the "take-makedispose" paradigm. The strategies will, naturally, have to recall the different kind of loops we have identified in the first chapter while analysing the general Circular Economy framework. As we have mentioned a few times and also reflecting the hierarchy of Waste according to the European union¹³, from waste prevention to any activity that imply having the item/device in use for longer should have the priority. The more the loop is internal ("Inner Loops" in the Circular Economy terminology), the more the value and the utility of the products/components is preserved.

Only after the potential to exploit those inner loops - Sharing, maintaining, reusing/redistributing, refurbishing/remanufacturing – is exhausted, recovery of materials should be performed, having in mind the design prescriptions we outlined in Chapter 1 and that will be mentioned again with a focus on electronic devices.

The first theme that will be discussed is reverse logistics, as any consideration on circular practice would be just theoretical without a solution that is, on the first place, deployed from an operational point of view.

3.2.1 Reverse Logistics and EEE

When it comes to put in practice activities aiming at closing the loop with electronic devices and, generally, WEEE, there are other factors such as quality, quantity and time that are involved and cause a higher degree of uncertainty and complexity with respects to the general discipline (Chen & He, 2010). The most immediate factor of complexity is that those streams comes mainly from three different sources: households, institutions and businesses. While households' range of equipment disposed is large, from big house appliances to small electronic equipment, large organization mainly discard information

¹³ Waste framework Directive 2008/98/CE

and communication technology. Households are able to discard a mobile phone which has ended its perceived utility/functionalities in different places/manners (Iacovidou, et al., 2017):

- Municipal collection points
- Local/Residential Kerbsides
- Special collection events
- Return it where it has been purchased
- Return it back to the manufacturer
- Give it to a recycler either appointed by the manufacturer or a third party one

In addition, the collected back resources have to be transported to treatment facilities to be tested, inspected, sorted and then disassembled according to specific product/component/material categories. Recalling the intelligent assets and the importance of traceability and product passport in the first chapter to see how it could strongly make this process more efficient, economically and operationally. Another factor of complexity is the difficulty of estimating which is the best available strategies to exploit what has been collected, depending upon the material content, its ease of disassembly and/or extracting components and the purity of the materials.

Sophisticated streams of research – more in the fields of logistics and engineering – have studied the reverse logistics by creating models that optimised the collection under several constraints. Among them, the key parameters that appeared as the most incisive on reverse logistics performance were the returned amount (27%), the quality (17%) and cost, prices, time and demand at 7% (Islam & Huda, 2018). Although less deepened, within the reverse logistic literature has emerged also the concept of a "Third-party Reverse Logistics provider", once the concept of third parties within the general discipline of logistics became to take place in the first decade of 2000.

In putting in place a reverse logistic system which is focused towards remanufacturing activities, it has been found that the location of treatment facilities is the key performance

indicator in designing a whole looping supply chain (El Korchi & Millet, 2011). When it comes to components/products that are collected back to be remanufactured, key information and key drives for success are also estimating the remaining life and the quality of what has been returned. Mazhar et al. (2007) have produced an approach to estimate the residual life of the minimum performance requirements of electrical and electronic components aimed at their reusing. The authors claimed to have designed a predictive maintenance system too to achieve process efficiency and predict the downtime of EEE collection and repairments in a CLSC environment. Others have developed mathematical tools to estimate the errors in the operational and economic efficiency of CLSC aimed at remanufacturing activities caused by the overestimation of the quality of the returned products (Van Wassenhove & Zikopoulos, 2010).

Complex and efficient reverse logistics mechanisms can be designed but it remains of a key importance the role of customers/end users. The role of governments, moral norms and willingness to sacrifice unused items have been identified as drivers for returning used mobile phones. In addition, as anticipated, in the first chapter, the disposal behaviour can be positively influenced by increased level of returns and incentives to the participating the collection back systems. Managers of reverse logistics systems should put in place contractual schemes to increase the volume of the WEEEs returned to be extracted value from (Dixit & Badgaiyan, 2016).

For the purpose of putting in place adequate reverse logistics systems, the PZB model – that identifies differences between expectation on the service quality and the actual performance of the organization – can be used. PZB model, within a Reverse Logistics in the mobile-phone industry environment, has showed some important factors that drive customers satisfaction and willingness to participate and join such systems being: Accurate pricing, motivation, possibility of upgrading the product for free during the warranty period, convenient location for product return/exchange, free repairing and post-repair notice (Lee, Chang, & Chen, 2007).

Some key principles about reverse logistics have been coupled with the remarkable challenges posed by the very nature of their objects when it comes to electrical and
electronic devices. Architectural complexity, quality of materials, retuned items destination, location of the Reverse Logistics facilities are huge points of marks when it comes to close the loop in a supply chain.

In the next section, as we are speaking of highly technological devices, considerations on intellectual property will be made.

3.2.2 Patents and Technology Licensing within a closed loop environment

Although the returns in terms of procurement, image and cost reduction of putting in place circular practices, collection of used products when needs to be performed far away from the product-selling location brings considerable transportation and inventory costs with it (Hong, Govindan, Xu, & Du, 2017). In choosing whether to embrace remanufacturing activities, manufacturers lack motivation and are limited by technology, market and long-term business strategies considerations (Matsumodo & Umeda, 2011).

Third party manufacturers can take advantage of this business opportunity by reselling remanufactured products on secondary markets or by reselling refurbished products on the same markets, going to compete with the original manufacturer of the device. From an intellectual property point of view, this is not possible as remanufacturing activities would need a manufacturer's patent licensing approval in order to make use of the components which are covered by patent protection. For example, Apple has recently subcontracted Foxconn to embrace remanufacturing activities in China with respect to End-Of-Life I-phones.

A still partially unexplored stream of research was born by joining technology licensing literature with closed supply chain in a technological environment. Huang and Wang (2017) have developed three remanufacturing models with a manufacturer a distributor (more likely to embrace those activities than a smaller retailer) and a third party under a technology licensing setting. The increase in efficiency of the remanufacturing ability would elevate the initial acquisition prices as well as the supply quantity of used product

and the profits of either the distributor or the third party, based on which player would receive the license to remanufacture the devices. Moreover, the more costs could be saved by remanufacturing, the more investments in Reverse Logistics system for the re-collection of devices would be charged on the acquisition price.

3.2.3 Design Strategies

As outlined in the first chapter, many problematics connected with Circular Economy implementation can be addressed at the design stage. A research team from Ellen MacArthur Foundation, created a framework for circular design of electronic products¹⁴, based – among the others - also on the findings of Rescom¹⁵. Design strategies need to be formulated starting from the specific approach that has been chosen to maximise the utility of a product in terms of time, performance, End-of-life uses and customer satisfaction in static/dynamic markets. We can cluster these design strategies in these categories based on the strategic objective pursued: durability, ease of maintenance and ease of disassembly to either adapt/upgrade or refurbish/remanufacture the device (Souchet, Meloni, & Sturges, 2017). Here, the underlying idea is the key importance of architectural modularity as a strategy to perform refurbishment, repairs and upgrades of single components without losing the residual value of the rest of the device (Ellen MacArthur Foundation, 2012).

I) Design for Durability:

¹⁴ Online Article: Souchet, Meloni, & Sturges: Your Circular Electronic Product Must Have These Three Features; December 6, 2017; Circulate news.org. Downloded on August 14 2018 at: https://circulatenews.org/2017/12/circular-electronic-product-must-three-features/

¹⁵ "ResCoM, which stands for Resource Conservative Manufacturing, has developed a collection of methodologies and tools for the implementation of closed-loop manufacturing systems. Co-funded by the European Commission, the project concluded in October 2017. The ResCoM outcomes help designers and manufacturers understand how collection, remanufacturing and reuse of products can lead to more profitable, resource-efficient and resilient business practices compared to the current linear manufacturing system." More at: https://www.rescoms.eu/

The objective is to make the user be satisfied to enjoy the product's utility for as long as possible. The durability can be achieved both at the architectural level, making the product and the connections between components last longer, and at a component level, whose durability should not vary with respect to the rest of the product.

This strategy does not cover exclusively the technical/performance aspects of a good, what has been defined "emotional durability" or "emotional design" is the design that aims at creating timeless designs that create emotional connections over time with the product. Sometimes, short time spans are the result of rapidly changing customer preferences rather that driven by effective functioning reasons. But, with respect to that, is a dynamic environment suitable for a design durability strategy? Of course, this kind of strategy is more suitable for markets that are more static both in terms of consumer preferences and pace of the innovation. Therefore, when deciding a design strategy, considerations on the stage of the industry needs to be done. e.g. Design for durability could be best for a mature industry, whose pace of innovation is low and both profit and demand are not declining yet.

II) Design for Maintenance and Repair: either by a technician or the user

A device can be kept in use for longer through a design that is – regardless of the actual performer of those tasks – maintenance and repair friendly. On one hand, the key factors to be addressed when maintenance and repairs are performed by a technician are to ease those tasks in order to create a perfect balance of cost and time effectiveness. On the other hand, if a product is designed to be user friendly with respect to those tasks, the driver for conceiving it should be to minimise the risks for the user to compromise the device, in terms of performance and aesthetics.

• Ease of product inspection: In the first chapter we have spoken of intelligent assets within an IoT ecosystem and their capability to perform

predictive maintenance. Knowing the conditions of each single components of a device is a precondition to design a device that is easy to inspect. Along with the tasks required to maintain or restore the device performance, information on the overall status should be: easy to assess for a technician but, especially, easy to understand, if the performer is the user. Visual clues are essential to address this issue.

- Ease to replace components within a still functioning architecture should be either time and cost effective for technicians (labour-component costs balance) or suitable for users that do not possess special equipment nor capabilities.
- Availability and affordability of spare components. Standardisation can furtherly help users, technicians, retailers and producers.

Fairphone exploits its strong modularity by design to make the users repair, refurbish and upgrade their devices with spare parts¹⁶ and online manuals ¹⁷. The only "special equipment" needed to repair a Fairphone is a screwdriver and some patient. Conversely Apple's Iphone decided to not delegate any repair/refurbishment activity to the users.

Some companies follow intermediate strategies: some parts can be repaired by users, in the case they possess appropriate knowledge and tools, others must undergo athe hand of an expert. Since some users may not be willing to perform themselves these tasks or lack sufficient skills, the scenario of full user-friendly repairability is not the only way forward (Ellen MacArthur Foundation, 2017).

III) Design for Adaptability and Upgradeability

When the pace of innovation is high, user requirements can rapidly increase or change along different drivers. Manufacturers of products should be aware of this and,

¹⁶ https://shop.fairphone.com/en/spare-parts

¹⁷ <u>https://support.fairphone.com/hc/en-us/categories/115000329046-Troubleshooting-and-Repairing-</u> <u>Fairphone-2?ref=footer</u>

through architectural design and modularity, making it possible to adapt or enhance some functions to match new user requirements without the need of marketing other new devices. Below, some key design factor to achieve this design strategy:

- Ease of components identification through performance evaluation and detection systems.
- Ease of replacing outdated components: those can be accessed in a cost and time effective balance
 Compatibility of components across product generations

IV) Design for refurbishment and/or remanufacturing

A technician or a third company should be able to restore the performance of the product to its initial original working condition either by refurbishing a part of it or by remanufacture the whole device with cost effective processes. The reusable components and their conditions can be easily detected so that they can be maintained in the process. To gain user acceptance, the aesthetics must absolutely be perfect. All the components that a user see and directly interact with need to be restorable at reasonable costs. Of course, in order to put in place a truly circular design strategy focused on refurbishment and/or remanufacturing, when the costs and the technological conditions make it possible, as much components as possible should be able to last multiple device lifetimes.

The ratio here would be to set principle and priorities for electronic industry designers. The strategies are not mutually exclusives and, as said before, should be adopted as a result of considerations on multiple levels of system in which the product will be used. On top of these design strategies, three general design factors should be pursued, no matter what the actual strategy is, in order to incorporate into an EEE business truly circular strategies (Souchet, Meloni, & Sturges, 2017).

- Materials should be chosen in order to (I) fit as much life cycles as possible and (II) those which are regarded as toxic by the regulations should be phased out. With respect to the former, using materials that can be recycled several times without losing quality (downcycling) can ignite a circle in which the materials exiting a recycling process will be used as an input. With respect to the latter, sometimes devices that contain hazardous elements such as heavy metals or certain chemicals which are difficult or costly to be separated from the rest of the architecture. Therefore, ending up being treated as a device that is wholly hazardous, with all the costs and losses of value it entails.
- Devices should be designed, as mentioned in the first chapter, to make the eventual recycling process as smooth and economically affordable as possible. Again, design-to-disassembly is the key. Main components such as batteries modules, screens and motherboards should be separable with cost-time effective activities. This can be achieved by:
 - Limiting the complexity of the material bills: pure materials are easier to process within a recycling process. Product passports can help the transition towards a more informatized and standardized system since they offer an overview of location and the material composition of each component (Ellen MacArthr Foundation, 2016)
 - Avoiding or try to limit adhesives and instead try adopting easy-access or "clip-hold" methods (Ellen MacArthur Foundation, 2012)
- Software compatibility should be ensured to enable and improve the hardware longevity. The information and operating system should not push the hardware to its limits, to ensure that the device can keep up with its performance requirements through time. The user should be taught and informed about the performance of its device and advised about the behaviours and conventionalities that can preserve its device from wearing. Moreover, the software should be able to upgrade the functionalities of the hardware. Functional upgradability can be obtained through conceiving leaner applications or through a shift towards cloud and fog computing, which will be furtherly addressed in this chapter

In moving around the pivot idea of a modularity need in order to achieve circulate design, it seems legit to wonder: what is the optimal degree of modularity in an electronic device? Fairphone and Google Ara – a google project for an entirely modular and customizable phone whose launch to the market has been suspended¹⁸ - have pushed to the limits the concept of modularity. Almost on the same page the dutch Headphone manufacturer Gerrard Street¹⁹, selling music as a service.

Decision on the degree of modularity must be assessed also in terms of overall size, appearance to the costumers and economic viability. What seems clear is that -again - a one size fits all approach is not the way forward. Thinking about Iphones which undergo the in-house maintenance process, 85% of them present just a cracked screen, showing that the device probably does not really need to be fully modular.

It has been deducted - along with designers, repairers and recyclers that have been interviewed – that a way forward could be a partial disassembly that has the pros of fostering (I) an ease of repairing the main components of a device and (II) substitute them in case of refurbishment activities (as well as (III) increase the operational and economic effectiveness of the recycling process in terms of material recovery yields (Souchet, Meloni, & Sturges, 2017).

3.2.4 Standardisation: implications on circular practices

Electronic and ICT industry is strongly dependent upon standards, both for hardware and software-based products/services. Some studies have highlighted the need for standardization activities as a key action for achieving material efficiency. Moreover, standards are the basic case of an innovation process that does not occur in an isolated way but it is characterised by collaboration and interdependencies with other players,

 ¹⁸ Google confirms the end of its modular smartphone of the Project ARA: <u>https://www.theverge.com/2016/9/2/12775922/google-project-ara-modular-phone-suspended-confirm</u>
¹⁹ https://gerrardstreet.nl/

constituting incentives to achieve concentrated efforts towards innovation (Goluchowicz & Blind, 2011).

As the costs of embracing circular practice to finally be able to "close the loop" might appear remarkable, establishment of industry standards can create the right alignment of incentives to better establish cross-chain and cross-sectoral collaborations. In addition, standardising components across models or even brands can increase the ratio for adopting collection systems as the costs of a more standardised process will be more justified by higher yields (Ellen MacArthur Foundation, 2012).

In differentiating a component standard from an interconnection standard, different outcomes could be achieved.

- A component industry standard could be established to both develop a circular movement of components to be exchanged between manufactuers/retailers/users or to establish criteria with respect to the materials to be used and their purity, in order to increase the yield of the eventual material recovery process. The more a component is standardised, the more circular solutions like collection of devices/components can be better achieved also between manufacturers that do not present huge market shares or be economically viable when the geography of their diffusion would be prohibitive.
- An interconnection industry standard could mean that while there is a continuous evolution of components to follow the changing market requirements in terms of performance, a basic architecture/interface allow for their integration, compatibility and Interchangeability. As long as the standardised architecture works, components manufacturer could compete between themselves to constantly upgrade the overall device when returned to be refurbished.

While adoption of truly circular industry practice could benefit from both approaches, the outcomes of standardisation in a circular economy framework remain unclear due to a lack of research.

What is less certain is that complexity of electronic devices coupled with a structural lack of strategic view in investing in disassembly, refurbishment and recycling activities cause these processes to be mainly labour intensive and also manual (Ellen MacArthur Foundation, 2017). This makes it worthy of further explorations to reach better cost-time equilibria. Standardised architectures or components could make it easier and economically rationale to invest in developing processes that increase the automation and therefore the yield in terms of products processed. In addition, if the object of the process increases its degree of standardisation and let the process do the same, with all the quantity and quality effects it would have on the outcomes, it would increase the opportunity cost of not operating those activities.

3.2.5 The diffusion of Cloud Computing

Interesting is how the widespread importance of cloud computing might be a big driver in changing the demand for greater storage and computing capacities in our devices. As the information are not stored in our devices, their processing can happen remotely. Therefore, IoT based schemes can increase the physical resource productivity by virtualising every aspect of a device but the core physical function of the equipment, e.g. the interface (Ellen MacArthr Foundation, 2016). Earlier devices and components will be kept in use for longer as their computing power and storage capacity will be optimised. In addition, some researches have studied the effect of this dematerialisation of electronic appliances on user perception, as the users will be more attached to their virtual streams of data and application rather that the device itself (Wilson, et al., 2017). Further research should be performed on the willingness to abandon ownership of devices as they become a mere access portal towards their dematerialised digital assets. Within this view, devices could become interchangeable and also not brand new as long as they guarantee an optimal connectivity with the network of intelligent assets (Ellen MacArthur Foundation, 2017).

Connectivity appears to be a key asset within this 4th industrial revolution. As long as an IoT infrastructure will be deployed, a physical device will have to be perfectly connected and synced rather than "in tune" with the market requirements. Within this view, it can

be stated that – yes – hardware capabilities become less important than connectivity (Ellen MacArthur Foundation, 2017).

On the same page of Cloud computing we find the concept of Fog Computing. Fog computing is a horizontal architecture that distribute computing power and resources, storage, control and network functionalities to the infrastructure that connects the cloud to the IoT network of the various intelligent assts. It all happens in a relentless way, as the objective of fog computing is to smooth and foster the informational efficiency of cloud networks. On one hand, it takes computing power demand away from the devices themselves, and on the other hand, solve the problems connected with minimum standards of services when certain powerful connectivity and data processing cannot really happen on the IoT devices alone (Bonomi & Milito, 2012).

3.2.6 User Perception

There is a theme of user perception when it comes to used and/or refurbished electronic devices. As the degree of technological innovation increases, refurbished electronic devices still find the majority of consumers cautious. Some credit card companies even offer different coverage policies when it comes to buy a refurbished device: 66% of credit cards in a study offered coverage with refurbished products that have a pre-existing warranty²⁰.

Some studies (van Weelden, Mugge, & Bakker, 2016; Hazen, Overstreet, Jones-Farmer, & Field, 2012) have highlighted how many potential consumers appear to be not aware of the refurbished device option because of they are not available – or enough visible – in their familiar retail channels. This prevents, many times, the potential consumer from even entering the initial consideration phase of consumption of a refurbished device. On top of that, the lack of general awareness and misconception of the refurbishing concept and technical process, preventing them from entering the evaluation phase of a device.

²⁰Alina Comoreanu, Credit Card Extended Warranty Study: 2017's Best Cards; (14 November 2017). Available at: <u>https://wallethub.com/edu/credit-card-extended-warranty-study/25686/</u>

The degree of misconception makes some customers unable to perceive and/or understand the differences from a refurbished or a second-hand device (van Weelden, Mugge, & Bakker, 2016; Hazen, Overstreet, Jones-Farmer, & Field, 2012).

It has been showed that 50% of users would be eager to possess a used or refurbished device, but under the right conditions (Mugge, Jockin, & Bocken, 2017) being:

- Additional services: Pairing up the refurbished smartphone with additional services can reduce the perceived financial and performance risks (van Weelden, Mugge, & Bakker, 2016). Allowing consumer longer trial periods or guarantee extended Warranty plans in terms of time (e.g. Samsung and Apple guarantee their refurbished devices for at least a year) or coverage (e.g. water drop, hardware damages, drop damages) are some examples to be adopted.
- Informational gap: Reassurances about the fact that the refurbishing activities are not just aesthetic but outcomes of detailed inspections of performance and single components²¹. Quality certification can surely tackle this perceived risk (van Weelden, Mugge, & Bakker, 2016); e.g. a third-party certification system could help the industry to establish some perception of reassurance among the potential buyers.
- Product-related incentives: improved battery-life, software upgrades, performance improvements, renewed or powered screen and/or camera, Innovative feature and connectivity devices (e.g. NFC). Not all devices make it possible to enhance the functional performances, but design strategies e.g. in smartphones can unlock many opportunities for enabling even hardware upgrades in future refurbishing process (Rathore, Kota, & Chakrabarti, 2011; van Weelden, Mugge, & Bakker, 2016).
- Environmental mission: Although environmental motives are still secondary with respect to the financial benefits of a refurbished phone (Wang & Haxen, 2016), some studies have highlighted how communication about the environmental benefits connected with the whole stream of resource-efficiency of circular

²¹Tercius Bufete, Should you buy refurbished electronics? (April 20, 2018). Available at: <u>https://www.consumerreports.org/electronics/should-you-buy-refurbished-electronics/</u>

economy could alter the perception of consumers and have a positive impact on the degree of adoptions (Harms & Linton, 2015; van Weelden, Mugge, & Bakker, 2016).

As mentioned in the chapter introduction, companies should target the correct customer segment when proposing the above-mentioned incentives. Theory of individual differences prescribes that differences in consumers' personality, skills, history and knowledge wll be reflected on their behaviour at the consumption stage. Some kind of users such as "techies" and "status quo/fashion-oriented" might not be interested in refurbished phones and will assume a higher financial or performance risk or some will just want a newer device in order to not be left behind. On the other hand, sustainability enthusiasts or casual utilitaristic users would be more willing and therefore sensible to communication on refurbished phones (Mugge, Jockin, & Bocken, 2017).

Big data and advanced analytics can increase the yield of a matching exercise to supply different customer segments exactly their desired function and, at the same time, organise efficient and predictive reverse logistic in order to migrate the devices towards less exigent consumers (Ellen MacArthur Foundation, 2017). Within this view the cascading processes can take place also between different consumers, as the potential utility and performance of the device – or its components/main architecture – decrease.

3.2.7 Residual Value: how virtuous loops that speed up the adoption process could be ignited

Right after some principles on user perception towards devices that undergo a refurbishment process, we can state that the Residual Value is something – utility, emotions, performance potential – that is perceived as still embodied in a device. If all the above-mentioned factors have an impact on this perceived value, their connection to it should be furtherly explored in order to reinvent the relationships of consumers with electronic devices.

Below some examples of a prospective virtuous cycles that could be ignited by a corporate initiative that goes in the direction of adopting circular practices, in this case of refurbishment (Ellen MacArthur Foundation, 2017).

- Believing in the refurbishment alternative and therefore using corporate efforts to develop technological and logistic improvements to the whole process is likely to increase both the residual value of used devices – as their utility can still be exploited through refurbishment – and the value of the refurbished devices themselves as their performance will improve. Profits will be gained by the manufacturers/refurbishers so that they will be able to invest in more sophisticated and standardised technology and processes
- As the refurbishment activities improve their productivity, the refurbished device will compete with the new ones. Larger pools of resources for the process could be reached as larger clients, such as businesses, will be tempted to sign advantageous contracts that involve take-back schemes. The value of used devices increases as there is a proper rising market in need of still functioning components.
- As companies will start to modify their business models to unlock the potential of circularity and their design strategies will start prioritising the efficiency over time of the device resources, their devices will retain more value at the end of each use cycle.

All these loops are likely to generate quantity and quality waves across the established practices that will slowly break through the consumers' acceptance, that will benefit from having a direct demonstration of a prove, solid and working concept.

3.3 Smartphones and Circular Economy: current trends

Can Smartphone become an example of a circular electronic device? After steep and increasing global selling rates, penetration of new models is slowing down – especially in wealthy economies.

This deceleration has been explained, by some authors, by a change in the innovation rate of the industry. As already mentioned, the moment in which a smart device is discarded is not often linked with its actual malfunctioning, worn out conditions or presence of damages. Often, this happens because the key obsolescence to be observed is with respect to – yes – new system requirements (e.g. upgrading smartphone applications sometimes, in scaling their computing power demand, puts older HWs out of market) or demand for better SWs, but mostly because of culture-driven factors such as willingness to own newer models (Watson, et al., 2017). Wanting the latest models has been estimated, by various authors, to be the main factor in driving smartphone replacements in the mass market (Taffel, 2012; Storm-Mathisen & Slettemeås, 2016). If the market has made the average consumer used to continuous innovations and "killing" new features, consumption paths has been shaped by a sort of "cult of the newest model". Most consumers want to experience the edge of the consumer electronic innovation by possessing the new device. Here is why, especially in developed countries, the slowing down of new smartphones sells can be explained by the fact that most people already possess a sophisticated and powerful device and now the innovation model makes the technological changes from one model to the other being more incremental than disruptive (Gartner, 2016; GfK, 2016; Cecere, Corrocher, & Battaglia, 2014).

Having the consumers always more satisfied with the actual level of performance caused secondary markets for smartphones to grow: a phenomenon that, in the precedent decade, has been observed more in developing countries. In fact, in 2013, before the secondary markets of mobile phones underwent an expansion also in the developed countries, it was estimated that 70% of phones collected for reuse in our western economies were following a flow towards developing markets to be sold cheaply ad satisfy lower

expectations and market requirements (Green Alliance, 2015). A study revealed how two thirds of smartphones in U.S. and in Germany enjoy a second life within a secondary market. The worldwide market for second-hand or refurbished phones is expected to reach 120 million units by 2017, with wholesale revenues doubling from 2014 value: from USD 7 to 14 billion²². This is likely to force, according to a Gartner researcher, Original Equipment Manufacturers to look into the secondary market for phones and formulate strategies to turn these phenomena in an opportunity for their businesses, as the revenue streams of all those involved in smartphones' supply chains could be affected.

There are multiple parties at a stake in the smartphone industry. That is why it could be useful to identify them before starting to formulate a circular industrial structure to adopt circular practices with respect to smartphones.

- Mobile phone producers or Original Equipment manufactuers are, of course, the key player here. They have a licensing power towards potential collectors/repairer/refurbishers. In addition, recalling the previous paragraph, most of the circularity can be eased at the design stage, power to embrace design strategies for durability and/or disassembly together with the production of spare parts. Currently, if the main players such as Apple, Samsung, Sony and Nokia are making timid steps, there are startups such as the already-mentioned Fairphones who have built their business models around the idea of circularity.
- Electronic retailers can work as intermediaries in the collection/reverse logistics process. Some EU countries that have received EU directives on WEEE have obliged these actors, above a certain size threshold, to act as collection points for WEEE. If regulation on one hand can ignite these practices, why economic benefits should not?
- Network service providers and phone carriers: they remain the larger sellers of mobile phones through both subscriptions and direct sell. They can drive consumption paths and spread service-based business models by coupling smartphone access to network access

²² Gartner, Gartner Says Worldwide Market for Refurbished Smartphones to Reach 120 Million Units by 2017. 2015, February 16. Accessed on 05/09/2018 at: <u>https://www.gartner.com/newsroom/id/2986617</u>

- Mobile Phone Repairers, either authorised or unauthorised, are a direct consequence of consumers holding their phones for longer and the development of a secondary market for mobile phones. Consolidation of the market pass through original manufactuerers demanding for these centers to obtain certifications in order to prolong warranties also after their repairments.
- Second-hand sellers and refurbishers: though a lot of second-hand trade happen in a C2C manner, there is an increasing number of shop and chains that trade in second-hand ICTs with proper warranties. There is an overlapping between the resellers/refurbishers and the repairers (Watson, et al., 2017).

In order to make the smartphone industry truly circular there are general schemes that could be followed. On the big picture, the big distinction is again between:

- Ownership of the device to the consumer: in that case manufactuers or the service provider which has been contracted to perform reverse logistics activities will need to build incentives such as trade-in programs such trade-in or buy backs, where the device is exchanged back for other benefits
- Ownership of the device to the manufacturer/service provider: in that case forms of usage such as leasing can be promoted.

Once this first distinction has been made, the bigger effect is given by a supply of used phone coming back from the market. As mentioned in the second chapter, taking aside the activities that need to be embraced regarding testing and inspecting the devices, that will generate the decisions with respect to the level of reusing activities (product, component, material), old devices have potentially multiple potential destinations. Once they are refurbished, possibly not by an uncontrolled third-party, they can be either given back to the same market segments it has been drained from or cascaded back in terms of market segments – directing it towards other less demanding customers – or geographically, towards developing countries.

Right now, most of circular business models within the industry entail take-back and buyback programs (Watson, et al., 2017). For example, Apple announced the beginning of some global take-back systems for I-phones and other product lines in 2016. Apple "GiveBack" is a take-back program that is jointly organised with selected partners that perform the "engine" activities of the reverse supply chain. At that point a decision is taken on whether the device's architecture or components can still give utility – in that case the device will be remanufactured by external partners - or if all of some parts of it should be recycled – in that case it would be sent to external recycling third parties²³. All those product acquisition management activities are performed behind a promise of an actual credit give to the customers returning their devices. The first monetary estimation will be either confirmed or renewed after the inspection and the customer will be able to accept it and get the credits or receive the phone back. Witnessing the attention towards older devices, Apple also propose a free post-consumption disposal of old devices when a new one is bought, bearing the operational costs with the potential of monetizing whatever residual value there might be²⁴. Samsung does something very similar even if it is not clear whether the actual activities are performed in-house or outsourced.

With respect to phone carriers, it is remarkable the observed tendency of customers towards sim-only plans paired with a spreading rejection of bundled phone and services offers. Above the others, there are new initiatives being kicked to achieve higher customer loyalty even though those do not represent much profit for the operators: one of those is the "Upgrade Programmes". A program in which a customer is given the chance to replace their phone with the new model, without needing to finish off the rates to obtain its full ownership of the old one. Some operators have estimated that upgrade programs could comprise a quarter of the market by 2020 (Watson, et al., 2017). These upgrade programs, that usually can be activated after 12 months, represents a sort of hybrid model with the fully servicized product of a leasing contractual scheme. Some operators are also reported to collect those phones and sell them to refurbishers and resellers partners with

²³ https://www.apple.com/shop/trade-in

²⁴ https://www.returnprogramme-apple.com/collection-it/

the only clause that the resell cannot take place in the collection country (Watson, et al., 2017).

3.4Applying the Framework: the example of Fairphone

Fairphone is an Amsterdam-based company who, starting from a campaign about conflict materials in 2010 ended up three years later by leading a movement to support a fairer stream of industrial electronics. They did it by designing and manufacturing their own smartphone, called "Fairphone".

Since the beginning, the company has been very transparent in terms of its procurement sources, choosing always conflict-free raw and/or recycled raw materials, and in terms of the cost breakdown of its product. At the first Fairphone issue, the company declared that – among the EUR 325 consumer price – about $129 \in 2^{25}$ were to be assigned to Design, engineering, components, manufacturing and assembly costs. Their first models were bought on a crowdfunding base, going to finance also their very first batches of production. The manufacture of the Fairphone has been outsourced towards an external company called Changhog.

By 2014, Fairphone had sold more than 50.000 smartphones across Europe ²⁶. The fact that their first model, the Fairphone 1, had its production outsourced and based on a third party licensed overall architecture, created some control limitations over the selection of components and the procurement strategies. Togheter with their pluriannual strategy, it was announced a retirement from a licensed model, in order to develop a customisable mechanical design to better achieve the circular economy aspiration proper of the dutch company. Producing in-house design meant also accessing a wider room of opportunities regarding the supply chain and material decisions. Moreover, in-house design made it possible to innovate on the longevity and repairability of the phone's architecture and components²⁷ as no risks of infringements were present.

²⁵ Cost Breadown of the First Fairphone, accessed on 07/09/2018. Available at: https://www.fairphone.com/wp-

content/uploads/2013/09/Fairphone_Cost_Breakdown_and_Key_Sept2013.pdf ²⁶ Next Chapter in Fairphone's strategy: Outlook for 2015. Available at:

https://www.fairphone.com/en/2014/11/04/next-chapter-in-fairphones-strategy-outlook-for-2015/²⁷ Our approach to developing the next fairphone, available at:

https://www.fairphone.com/en/2015/02/12/our-approach-to-developing-the-next-fairphone/

3.4.1 Fairphone 2: concept and architecture

The design is the output of a process that started from identifying the factors that push people to replace their smartphones in order to eliminate them.

The first critical factor is fragility of the external layer of phones, which is often protected with additional layers of various materials (e.g. cases). Fairphone 2 was designed to have an additional layer of protection which is easily substitutable by users. A replaceable outer shell acts, therefore, as a protective case, taking the place of the classic architecture of back cover and battery doors ²⁸. Moreover, another key protective factors that smartphone users commonly expect from a case is a rubber rim that reinforce the edge of the glass: the most sensible part of the glass that represents one of the most replaced components in a smartphone. As a proof of design that is durability-focused, Fairphone 2 has also been tested to resist the impact from a reasonable height -1,85 meters - on all its surfaces for multiple times.

Now we come to the most important part of the Fairphone concept. The reason why it is being mentioned in this thesis. Fairphone 2 is an extremely modular phone which is therefore designed for an easy disassembly. In contrast with the industry's tendency to seal up all the components, in the sake of a device minimised thickness, Fairphone decided to reinvent an architecture that make it easier to perform assembly and disassembly services. At Fairphone, design for an easy maintenance that can be performed even by users themselves has been taken seriously. The innovative modular architecture it is based on make it easy, for anyone and without professional support, to restore back the device to its full functionality. In defining the KPI to be accomplished during the design phase, Fairphone has allowed a more relaxed constraint in terms of thickness to make it possible to increase the architectural flexibility and the interchangeablity of the standardised electrical interfaces.

²⁸ The Architecture of the Fairphone 2; Designing a competitive device that embodies our values. Available at: https://www.fairphone.com/en/2015/06/16/the-architecture-of-the-fairphone-2-designing-a-competitive-device-that-embodies-our-values/

Here's that the already-mentioned design-for-disassembly is pushed to the limits. The more a unit is commonly broken - e.g. the screen/display or the battery module - the more it can be replaced by owners without particular technical skills. With respect to the display, no tools at all are needed. The replacement can take pace in a couple of minutes. On the other and, other replacements - receiver, camera and speaker units - just need a regular screw driver. Many guides have been realised by the company and the screws are color-coded to accompany the user through the task.

In the below figure, an overview of the official shop of spare parts of the company. As it can be seen, subunits are easily identifiable by function also by a non-expert user.

Yes, you can repair it yourself

Where's my module?

- 1. Display Module
- 2. Camera Module
- 3. Battery
- 4. Core Module
- 5. Top Module
- 6. Bottom Module



Figure 3.3 Overview of the Fairphone official shop for spare components. Available at: <u>https://shop.fairphone.com/en/spare-parts/filter/choose-your-fairphone/fairphone-2</u>

Another implication of the modularity conceived by Fairphone designers is a sort of "Chinese walls" between the the major components which has been therefore divided in subsystems/subunits. If, for instance, the screen has been damaged and needs to be substituted, no other components will have to be thrown away together with the damaged screen. Functional division between units take into account the engineering complexity and cost of replacement to be designed. The electromechanical components whose the subsystems/subunits are composed of, being easily replaceable, need to be not soldered nor attached with glue. A truly modular design-for-disassembly should prefer screws and

clip-ons to glue and solder links, as mentioned also in the first Circular Economy's Manifesto from Ellen McArthur Foundation (2012).

3.4.2 Fairphone 2: Design-for-Upgradeability

Another interesting concept is a designed and well thought potential to bear further ugrades and expansion. As the pace of innovation and the additional market requirements can vary, Fairphone decided to leave a considerable room for single components enhancements as well as introduction of new features. Within the same architecture and using the same defined electrical interfaces, as long as the software related complexities have been addressed, flexibility with respect to hardware components make it possible to eliminate certain functionalities in other to expand others. An expansion port has been conceived to introduce, in a moment subsequent to the commercialisation of Fairphone 2, functions such as the NFC – which had not already been widely adopted – or the wireless charging – for which a widely adopted standard had not already emerged.

Therefore, as the market is shown new functions that are valuable to customer, a modular phone makes it possible to introduce them without having to buy the latest model. In addition, key performance parameters that drive the purchase of smartphones such as the back and frontal cameras – if designed and built within the same architectural requirements – can be upgraded to newer models and performance levels: e.g. IR camera instead of the initial rear-camera unit. That is actually what happened. Fairphone 2 has been launched in the end of 2015 with a 8 Megapixels and single flash rear camera and a 2 Megapixels front camera. In September 2017 the company has announced the launch of new camera modules that definitely made the Fairphone 2 upgradeable²⁹. As we already mentioned before, the subunit of the camera was one of the subunits that are replaceable just using a screwdriver. The company, by giving the users the possibility to upgrade their camera modules with a 12 megapixel and dual flash rear camera and a 5 Megapixel front one. Newly bought Fairphones 2 already came out with the new camera modules – with the relevant savings in designing, producing and promoting new models

²⁹ New camera modules make the Fairphone 2 upgradeable. 2017. Available at:

https://www.fairphone.com/en/2017/09/20/new-camera-modules-make-the-fairphone-2-upgradeable/

while the rest of the architecture remains more or less the same. Customers has been given the possibility to buy the rear camera module for EUR 45 and the front (selfie) camera for EUR 30, out of the EUR 525 initial price.

The Fairphone 2 is an example of a truly modular phone and the achievement of a fully design-for-durability strategy. In the next section, the final one, we will try to unite the concepts highlighted in the second chapter, on Closed-loop supply chains, and the concepts highlighted in this chapter on consumer electronics.

3.5 Putting things together: a strategic approach towards circularity within the smartphone industry

So far, we have reviewed what the Circular Economy is all about. Starting from the big picture and the school of thoughts to its operational implication in terms of Reverse Logistics. Lastly, we did a overview of the very undeveloped research literature on circular economy with respect to the consumer electronics, trying to outline the main themes and future reasonable evolutions it might entail.

Now that a comprehensive knowledge has been gained, it is time to outline an industrial approach towards the circular economy framework that could be followed within the smartphone sector.

Before, let us have a review of the main factors driving this model.

I. The pace of innovation of the industry, marginal value of time and design implications

The pace of innovation is slowing, as smartphone industry is gently approaching a mature phase of its cycle. Producers are striving to justify premium prices for new models as no new "killing" features are introduced. Moreover, as mentioned in the previous chapter, though still short, the average time before a smartphone is replaced is increasing.

In the third chapter we have mentioned how product design and strategies intertwine with respect to Closed-loop supply chains and business models. The pace of innovation made the industry's marginal value of time – the effect of time in terms of dissipation of a customer's perceived value of the product – high, meaning that the easiest and most defensive design and business model strategy were based on a single lifecycle. When this happens, the profitability lies more on resource efficient designs and economic efficiency of the manufacturing system. No interests are posed on the after-sale scenario. As the industry is getting more matured, smartphone manufacturers have the chance to change

their point of view and, as Fairphone company did, point on robust designs that are likely to achieve multiple lifecycles.

II. Hardware-as-a-service: switching to a product-service system

Switching to a service-based business model to retain the device's ownership. Contractual schemes that transform a passive consumer into an active user are essential to achieve circularity within this industry.

On one hand, the consumer renounces to own the assets but, on the other hand, it will be assured a usage which will be fit to its performance expectancy along the entire time span of the contractual obligation. A big obstacle in the industry today is that different types of customers with different type of performance requirements usually have to witness to their devices' gradual degradation, ending up buying another model. What if they could be part of a system in which they always gain the access to usage of a device that performs as precisely as they need?

On the other hand, as the ownership is retained, the manufacturers will have a full switch in their incentives. As the good remains in the service provider's balance sheet, there will be an interest to increase the productivity of every bit of the asset over multiple lifecycles. The concept of having a product just accessed by the user offers to producers a certainty, under some binding conditions, of getting back products at their end-of-use stage. Accordingly, the productivity of an asset that is given away, through e.g. leasing or payper-use, will need to be assessed also along the time dimension. Investments will be needed to put in place a proper closed-loop supply chain system to acquire the products back, testing and inspecting them and processing them accordingly.

III. Predictive Maintenance:

As we live in a world made of interconnecting and intertwining intelligent assets and smartphone are the symbol of this, Walter Stahel's "functional service economy" has

never been this close. Predictive maintenance should be exploited by service providers to predict usage ad wear patterns in order to plan and even sync the downtimes of each component within, for example, a refurbished architecture.

IV. Remanufacturing choices vs. third-party entrants:

One key take home of the second chapter was that third-party new entrants or potential new entrants in filling up a market space left by the absence of controlled reverse logistics systems cannot be ignored. As mentioned, the market for remanufactured smartphones keeps growing, starting to gain traction also in developed countries. Original equipment manufacturer cannot in any case find themselves behind other third-party and unrelated players. There is a specific risk that expertise and market presence could build a competitive advantage that manufacturer and their selling and service providers partners on the territory could not be able to contrast once the market explodes.

V. Different consumer segments with respect to refurbished phones

A segmentation of the usual smartphone consumers is vital to understand the model I will then propose. A first cluster can be called an "expert customer group". It is made by customers that are highly involved and passionate in innovation and technology. They value product-related incentives such as performance and new functions. Even though they usually tend to buy the latest model, they could be willing to buy refurbished phones if the latest state of art technology is present. Following the expert customer group, there is what Mugge et. Al (2017) have defined a susceptible follower. It is often found buying the latest model though presenting low awareness on technicalities but high susceptibility with respect to appearance and camera. Finally, one of the most precious segments for refurbished phones is the "casual supporter" one. A utilitarian customer that judges the smartphone as not vital nor need the latest technology to be satisfied. They hold a low technological knowledge and they perceive less performance risk in entering a contract that entails a refurbished phone.

VI. Non-authorised repairments

A huge loss of profits is represented by the existence of a market for non-authorised repairments and components. Apple thought that had solved these problems through the famous "Error 53" phenomenon which caused a device to impair at an operating system update when non-original components were installed in it. Unfortunately for them – but maybe fortunately for the price-sensitive consumers – the company had to solve the "bug" due to negative reactions from their market base ³⁰.

We have now all the elements to build a system that somehow addresses all the issues, challenges and themes presented in this work.

As the marginal value of our smartphone is decreasing, it is time to switch the industrial approach towards the business that is made out of our devices. The psychological barrier of the "loss" of ownership of the device is bound to be tackled by the original equipment manufacturer and their communication strategies. The smartphones out in the market should remain a manufacturer's asset and their management should be outsourced to an ecosystem of service providers that take care of the reverse logistics activities. Those reverse logistic activities should achieve the right balance between cost and time efficiency and at the same time having a smooth service as a minimum requirement.

What if the access to smartphones were given on a leasing-based business model and cascaded down, at a component-level, through less exigent customer segments along several time-slots before being ultimately either recovered – at a material-level – or sold in the secondary market?

As mentioned in the second chapter, a firm intended in achieving a Closed-loop supply chain strategy in a multiple product lifecycles environment needs to increase its degree

³⁰ Apple and Error 53: www.dailymail.co.uk/sciencetech/article-3453566/Apple-issues-fix-Error-53apologises-customers-faces-legal-action-following-warnings-update-renders-iPhones-unusable-breakslaws.html

of vertical control to assure that none of its value is spilled out towards undesired third parties. In this task, retaining the ownership of the assets help in preventing users from using not-authorised resources or parties to perform their ordinary and/or extraordinary interventions on the devices or sell value in the growing secondary markets. Let us explore this idea step-by-step.

3.5.1 Location of the facilities and centralisation: the key role of predictive maintenance

The location of the treating facilities, as already mentioned, is usually a critical factor of financial success of reverse logistics practices. Some have calculated that, in order to ignite a continuous rationalization and improvement process with respect to the core reverse logistics activities, the actual reusing operations, may those be refurbishing or architectural remanufacturing, should be better done at the distribution facilities rather than in the retailer shops. Therefore, we would be avoiding doubling the costs of transportation and logistics towards the pre-existing channels.

But, as the Dell-GENCO ATC case had outlined, some of the activities should be best done at lower degrees of centralisation. The ratio here is having stricter loops that avoids management and transportation costs when minor tasks are required. GENCO ATC could not be blamed for bearing a gridlock of devices to be tested, inspected and addressed towards the various reusing levels. The flows of devices to be – some more, some less – reprocessed should be discriminated upward. Within this view, predictive maintenance appears to be potentially the key towards achieving such complex systemic approaches in a manner that is perceived as smooth by the consumers/users. Mathematical, informational and managerial approaches have been ideated to estimate the residual life of the components within an EEE architecture and compare it with the minimum performance requirements that were previously established. Meanwhile, Intelligent assets' potential scope has increased and traceability of every aspect at the product, component and material level of a device should be brought towards perfection in terms of informational and, in turn, predictive power. As we have mentioned time-slots, similar to the upgrade programmes that had been promoted by the phone-carriers companies at a

retail level, the predictive potential of a Closed-loop supply chain is essential to either anticipate any disruption in the usage – that, being service-based, should be guaranteed and as smooth as possible – but also to gain technical insights that somehow help design, procurement and engineering planning of the wearing and performance patterns along those slots. With respect to the Dell-GENCO case, as the outsourced treatment facility was preventing Dell's designers from gaining actual insights on the product design, informatising any aspect of this information flow is essential: predictive maintenance could be a solution to this loss of market information within an outsourcing environment.

3.5.2 Towards smaller loops: decentralisation of the activities through design strategies

Thus, we are talking about a reverse logistics system that should be centralised in its higher complexity activities (such as unexpected/unidentified defections or more capital/skill exigent remanufacturing and refurbishing activities) but, at the same time, decentralised in as many aspects as possible to smooth the service up and decrease the costs that, as we mentioned, are well influenced by transportation and facilities' location. Decentralisation should be achieved upward by simplifying, at a design stage, tasks such as maintenance and product substitution. Design-for-disassembly has been a sensible topic for phone manufacturers because of the risks - often concrete - that non-authorised repairments, refurbishing and remanufacturing activities could steal business to the original and licensed channels for repairs and/or components' substitution. While some, like Fairphone, went for a potentially total delegation of the disassembly and maintenance activities, others like apple decided not to delegate any to the end consumer to gain as much value as possible through the official and authorised channels. In this model the ownership of the asset is retained though, implying that no user would have an incentive to operate "pirate" or not-authorised task of any type because of the risk of undergoing some penalties. As a leasing contractual scheme should be as flat as possible - except from damages that are direct user's responsibilities that could still however be addressed with additional warranty proposals – ordinary substitution of the components should be included since no user should be charged for performance pitfalls of something that has already undergone at least one lifecycle.

Modular designs and extreme simplicity of performing the ordinary maintenance, represented by the Fairphone 2 concept, could have a double-folded effect with respect to both substitution of components or upgrading of new functions - still through mechanical substitution or addition of new modules (see the NFC case or the new featured cameras in Fairphone 2). On one hand, the skill, capital and labour exigencies of substituting a certain component could be strongly tackled down. Just one screwdriver and some basic know-how together with the manuals and the instructions could be needed to perform the activity. Meaning that this activity could be delegated to actors that are diffused in the territories, going to strongly tackle the transportation costs. On the other hand, as the degree of complexity is very low and the risk of compromising the actual performance and/or aesthetics of the device is minimised, users could perform repair activities themselves. Why should they? To get rewarded! As stricter loops mean lower transportation costs and the self-management of a user's device is a further saving in terms of commissions to capillary contracted collaborators, there are the elements to make a win-win situation out of it. Small incentives – such as discounts on flat rates – could be promised to "virtuous" users that perform maintenance without involving the official repairer. At that point, the cost for our service provider would be the logistics associated with sending the new components.

To recoup, as the design strongly foster disassembly, substituting and even introducing new functions to the initial architecture, the outsourcing that would be performed is even more hybrid as it involves externalise part of the activities toward the paying user that becomes the part of a circular chain.

3.5.3 The last building block: cascading strategies through customer segments

As we have defined the concept of "cascade" as the prioritisation of reusing activities aimed at preserving the user's perceived residual utility, the business residual value and ultimately the economic consistency of the residual scrap value of the materials. Cascading process could mean, once assumed that a whole product could not be resold, break it up in its components and consider it then its usage within other products and just at the end consider a material recovery. "Engine" activities of the logistics – testing,

inspecting, disposing - can give indications on the highest value use that is potentially performable.

In a service-based environment with respect to smartphone, performance – together with the service level - would be the ultimate driver of the contractual relationships with the user on the demand side. Users and their emotional and functional needs are what builds the market requirements thresholds that, suddenly, will be analysed and compared with the conditions of returned product and their components at a reverse logistics stage. We have mentioned the existence of different consumers' clusters with respect to new and refurbished smartphones. How devices are used to be globally cascaded from developed to developing countries, why should not they – or their components – be cascaded from high-end users towards lower end ones?

Upgrade programmes, chosen by many carriers to improve their customers' retention, make it possible for what we have defined the "expert customer group" to keep switching to the latest model and enjoy the satisfaction of using the latest technological innovation and functions. In a hypothetical price differentiation, those are the types of customers who would maybe be willing to pay more to always have the latest model. In this first part of this business model, the first expert and technology – or maybe mainly to a design enhancement – at the end of each time slot, may that be 12 or 18 months.

Once a first wave of newest models will be returned through proper reverse logistics activities, the components that meet certain performance and status requirements will be used to either upgrade or refurbish a second – lower end – group of devices. This is potentially a multi-stage business model in which components could be cascaded down towards price-sensitive less exigent and more market segments. The products/components that are judged as not capable of sustaining other life cycles have two main alternatives. Either they could be separated in their materials and recycled, going to be part of the next generation production: here the importance of material purity and design for recycling. Or, conversely, sent through secondary market channels towards

- but not only - developing countries in the form of components or in the form of a - reprocessed and reassembled - product.

As in the "Lake Economy" theorised by Stahel, circular practices in a closed-loop supply chain environment where the results in terms of performance and efficiency are sold rather than the good's ownership alone, life extension of products would be guaranteed guaranteed and the value of the existing stock exploited until its depletion.

Conclusion

Circular Economy offers an alternative view of what the industrial system as a whole could become. In the very first chapter it was stated the willingness to take aside environmental and social reasonings to justify the importance of the framework, trying to focus on the business advantages that could be unlocked by the interested parties. Though for many those reasons would be more than enough to ignite changes in the global philosophy towards production, major business changes can be ignited either by a financial convenience in terms on returns on investments or by new policies' pressure.

Governments' awareness and increasing attention of the policy-makers, especially at the European level, together with the major technological advancements can be a strong driver for the adoption of the circular industrial model. On the other hand, the main barriers appear to be the culture – even though environmental awareness and sharing economy can help – and the market – need of high upfront investments and absence of collaborative behaviours for the sake of differentiation (e.g. Standardisation of components).

The concept of a restorative industrial systems stems from achieving what it has been defined a "cascade": the concept of performing the highest value activity that preserve the residual utility of a product, component or material. The more the activity that is performed is conservative - starting from the landfill disposal to recycling, passing from remanufacturing, refurbishing or full reusing of a product – the more residual value is preserved and/or furtherly exploited. Thus, putting in place "cascade" processes means differentiating after proper testing and inspecting – at product, component and material level – which is the most profitable activity and then behave accordingly.

The key challenge for a Circular Industrial Model to scale up from small start-ups reality might be the switch toward a "functional service economy" where ownership of products will be retained and the access to a device's performance and related service, rather than its possession, would be the object of the transactions. Companies performing this business would have interests to generate designs and logistics systems that aim at increasing the return of every bit of the assets they possess through circular practices. Examples come from Michelin "pay-per-kilometer" contracts or Philips lighting's "lightas-a-service". With respect to Smartphones, leasing contracts could match actual performance over time with the related market requirements thanks to continuous refurbishment, component substitutions or enhancements/upgrades.

In designing a proper Closed-loop Supply chain, managers should take into account the actual or easily developable core competencies in acquiring, inspecting and reusing together with the design strategy and the nature of the product, being either a single or multiple-lifecycles one. The marginal value of time - namely the decrease in the perceived value of a product over time - appears to be a key driver in the choice of embracing a Closed-loop supply chain strategy, as in a more stable and technologically mature market make it is possible to reuse as much residual utility and/or value as possible. It has been observed how returned consumer products are more likely to retain residual performance potential as opposed to the industrial ones that underwent a more extensive use. Generally, as the design strategy aims at creating lasting products, core competencies in exploiting the benefits of reverse logistics should be developed because what is not performed in a post-sale stage is likely to be performed by other third parties. In fact, as the second chapter revealed, no manufacturer should ignore the existence or the potential rise of secondary markets for either used or remanufactured goods but rather try to increase its degree of control over what happens in the post-sale stage, especially if its products/components/materials have robust nature that can be prolonged over more than one lifecycle. Regaining the control over post-sale activities may be difficult once third parties have specialised and gained market recognition into a growing secondary market.

If centralisation may be needed to achieve the right balance of control of the activities within a Closed-loop supply chain environment – e.g. single remanufacturing facilities, decentralisation of as many activities as possible should be performed with the aim of achieving stricter "loops" with respect to testing, inspecting, refurbishing, remanufacturing, remarketing. Meaning delegating those, even to consumers themselves, could lead to higher exploitation of the residual value/utility together with lower logistics burdens.

Generally, third-party involvement can fill in the absence of proper core-competencies in reusing activities. In vertically integrated Closed-loop supply chain strategies there are

complexities with respect to procurement and bulk buying decisions, operations planning and plant capacity together with the risk of cannibalization. Outsourced CLSC strategies can be put in place through contractual obligation and through licensing intellectual property. Once the forward logistics has been outsourced, performing the remanufacturing activities of the reverse logistics in-house can be too costly. It is important to coordinate the information flows and insights from returned products/components and prevent it from being kept between the walls of the third-party partner.

With respect to remanufacturing activities, twisting findings have been observed at a consumer behaviours level. The presence of remanufactured products on the market always causes positive effects on the perceived value of the new one, but the results are ambiguous when the remanufactured alternative is proposed by the same original manufacturer. With respect to that, sometimes it may be beneficial having the original manufacturer still performing the remanufacturing activities but selling the products under a different brand or in a different market channel.

Consumer electronics and its appalling global waste streams generated are of a primary importance to be implemented with Circular Economy practices. The highly technological components with their residual performance potential even before the presence of precious metals at a material level justify the attention to the topic. The main barriers are: market acceptance, architectural complexity, product acquisition practices and location of the reverse logistics facilities.

Design is a pivotal theme with respect to adopting a circular industrial model. We have explored its mandate of reducing unrecoverable waste at the very source of a product but also, especially through achieving modular designs, its potential of fostering disassembly and recycling activities in a reverse logistics environment. In addition, it can make it possible to achieve a truly design-to-upgradeability strategy since a product's architecture can be renewed with new components or even enhanced with new functions within the same system of electrical and mechanical interconnections. Introducing a higher degree of modularity, as Fairphone did, can entail risks of not-authorised repairments and spare parts but they can be tackled through business models that entail the switch from producers/sellers towards service providers, where the ownership of the devices is
retained. Standardisation of some components, interconnections or remanufacturing activities could ignite concentrated efforts to put in place collaborative reverse logistics systems and also increase the availability of spare components/resources to put in place circularity also in more remote locations.

In addition, it is worth mentioning the prospective role of IoT and Fog Computing on retrieving computing power and data storage demand from the devices, making it possible to challenge the concept of hardware towards a mere interface with a digitalised infrastructure.

Reasons for the adoption of a circular industrial model in the Smartphone industry have been found in the decreasing pace of innovation, the increasing average replacement time and the rising of input prices. Based on the findings on the literature streams of research with respect to Circular Economy, Closed-loop supply chains, Consumer Electronics and Consumer behaviour with respect to refurbished devices, many factors were identified and addressed with a hypothetical model of Circularity within the smartphone industry. The model is based on a service-based agreement with different types of consumer which are differentiated based on their buying attitudes, technological requirements and the willingness to obtain the "latest model", which has been highlighted as one of the main drivers in consumers behaviour.

Consumers are different in their attitudes towards consumption of electronic devices. Big data and advanced analytics can increase the yield of a matching exercise to supply different customer segments exactly their desired function and, at the same time, organise efficient and predictive reverse logistic in order to migrate the devices towards less exigent consumers. Within this view the cascading processes can take place also between different consumers, as the potential utility and performance of the device – or its components/main architecture – decrease.

As it happens with upgrade programmes, some users that pay a premium price will have the possibility to always use the latest model while the components of the "previous" newest one will be cascaded down towards less exigent customers into refurbished and/or remanufactured architectures. Following the Fairphone 2 example, achieving an extreme degree of design-for-dissassembly could have remarkable impacts in terms of reverse logistics costs as the repairment, substitutions or even upgrading can be better delegated in the territory or even to the users themselves. Exit stages from the "loops" would be activated for not-reusable components and/or materials. The two main alternatives identified would be secondary hand markets – especially towards developing countries – or material recycling.

On the basic idea of Stahel's "lake economy", a pool of resources circulating between different type of users and refurbishing facilities could be the way forward into the smartphone industry. In addition, the idea that some ordinary tasks could be delegated even to users that are willing with zeroed transaction costs and payment through credits and discounts on the service is interesting and worth of further research. What if remanufacturing were made so easy it could be "out-sourced" to users?

In conclusions, advancements of the industry towards circularity can be ignited by both design strategies and investments towards establishing Closed-loop supply chain that make it possible – if accompanied by contractual forms that imply either take back incentives or products as a services schemes– to perform a control of the assets' lifecycles in order to smooth up the perception of such services, its operational efficiency and the profitability over time – at the product, component and material level – of each asset that is immitted into the market.

Bibliography

- Abbey, J., & Guide, V. (2017). Closed-Loop Supply Chains: A Strategic Overview. In Y. Bouchery, C. Corbett, J. Fransoo, & T. Tan, Sustainable Supply Chains. Springer Series in Supply Chain Management, vol 4 (pp. 375-395). Cham: Springer.
- Abbey, J., Meloy, M., Guide Jr., V., & Blackburn, J. (2015). Barriers and Strategies for Product Reuse in Consumer Markets. *California Management Review*, 57 (4), 26-42.
- Accenture. (2014). Circular Advntage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth. Accenture Technology.
- Agrawal, V., Atasu, A., & Van Ittersum, K. (2015). Remanufacturing, third party competition, and the perceived value of new products. *Management Science*, *61*(1), 60-72.
- Atasu, A., Guide, Jr., V., & Van Vassenhove, L. (2010). So What if Remanufacturing Cannibalizes New Product Sales? *California Management Review*, 52 (2), 56-76.
- Baldé, C., Forti, V., Kuher, R., & Stegmann, P. (2017). *The Global E-Wast Monitor*. Bonn/Geneva/Vienna: United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA).
- Baldé, C., Wang, F., & Huisman, J. (2015). The gobal e-waste monitor. Bonn, Germany: United Nations University, IAS - SCYLE.
- Basel-Convention, U. (2012). Guidance Document on the Environmentally SoundManagement of Used and End-of-life Mobile Phones. *Prepared by MobilePhone Working Group*,.
- Beamon, B. (1999). Designing the green supply chain. *Logistics Information Management*, 12 (4), 333-342.
- Benyus, J. (2002). Biomimicry: Innovation Inspired by Nature. Harper Perennial.
- Bonomi, F., & Milito, R. (2012). Fog Computing and its Role in the Internet of Things. *Proceedings of the MCC workshop on Mobile Cloud Computing*, (pp. 13-16). Helsinki.
- Botsman, R., & Rogers, R. (2010). What's Mine is Yours: How Collaborative Consumption is Changing the Wa we Live. Harper Business.
- Braungart, M., & McDonough, B. (2002). *Cradle-to-Cradle: Remaking the Way we Make Things*. North Point Pr.
- Cecere, G., Corrocher, N., & Battaglia, R. (2014). Innovation and competition in the smartphone industry: Is there a dominant design? *Telecommunication Policy* 39, 3-7.
- Chancerel, P., Meskers, C., Hagel, C., & Rotter, V. (2009). Assessment of Precious etal flows during processing of waste electrical and electronic equipment. *Journal of Industrial Ecology* 13, 791-810.
- Chen, H., & He, H. (2010). Reverse logistics demand forecasting under demand uncertainty. *ICLEM 2010 : Logistics for sustained Economic Development Indrastructure, Information, Integration,* (pp. 343-348).
- Chopra, S., & Meindl, P. (2010). *Supply Chain Management : Strategy, planning and operation (4th edition)*. Pearon Prentice Hall Inc.

- Clark, J., & Hunt, A. (2013). *Element Recovery and Sustainability: RSC*. Cambridge: Royal Society of Chemistry.
- Crosskey, J. (2015). Using The Internet of Things to detect asset failures before they occur. *IBM big data & analytics hub, 2 June 2015.* San Francisco.
- de Jesus, A., & Mendonça, S. (2018, March). Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy. *Ecological Economics*, 145, 75-89.
- DEFRA, (. (2015). *Emerging Findings from Defra's Regulation*. London: DEFRA. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment

data/file/406225/defra-regulation-assessment-2015.pdf

- Deloitte. (2014). Deloitte, The Internet of Things Ecosystem: Unlocking the Business Value of Connected Devices. Deloitte.
- Dixit, S., & Badgaiyan, A. (2016). Towards improved understanding of reverse logistics Examining mediating role of return intention. *Resources, Conservation and Recycling*, 107, 115-128.
- El Korchi, A., & Millet, D. (2011). Designing a sustainable reverse logistics channel: the 18. *Journal of Cleaner Production*, 19 (6 -7), 779-792.
- Ellen MacArthr Foundation. (2016). Intelligent Assets: Unlocking the Circular Economy Potential. McKinsey; Ellen MacArthur Foundation.
- Ellen MacArthr Foundation. (2016). Intelligent Assets: Unlocking the Circular Economy Potential. McKinsey; Ellen MacArthur Foundation.
- Ellen MacArthur Foundation. (2012). *Towards The Circular Economy Vol. 1: Economic and business rationale for an accellerated transition.* EMF.
- Ellen MacArthur Foundation. (2012). *Towards The Circular Economy Vol. 1: Economic and business rationale for an accellerated transition.* EMF.
- Ellen MacArthur Foundation. (2013). Towards The Circular Economy Vol.2 Opportunities for the consumer goods sector. McKinsey.
- Ellen MacArthur Foundation. (2014). *Towards the Circular Economy Vol. 3 Accellerating the scale-up across global supply chains*. Ellen MacArthur Foundation ; McKinsey.
- Ellen MacArthur Foundation. (2017). *Circular Consumer Electronics: An Initial Exploration*. Ellen MacArthur Foundation.
- Eropean Remanufacturing Network. (2015). Remanufacturing Market Study.
- Ferguson, M., Guide, Jr., V., Koca, E., & Souza, G. (2009). The value of quality grading in remanufacturing. *Production and Operations Management*, 18 (3), 300-314.
- Ferguson, M., Guide, V., & Souza, J. (2007). Supply chain coordination for false failure returns. Manufacturing & Service Operations Management 8(4), 376-393.
- Ferguson, M., Guide, V., Koca, E., & Souza, G. (2009). The value of quality grading in remanufacturing. *Production and Operations Management* 18(3), 300-314.
- Foundation, E. M. (2015). *Growth Within: A Circular Economy Vision for a Competitive Europe*. McKinsey.

- Frosch, R. A., & Gallopoulos, N. E. (1989). Strategies for Manufacturing. *Scientific American*, v261 n3 p144-52 Sep.
- Gartner. (2016). Gartner Says Global Smartphone Sales to Only Grow 7 Per Cent in 2016. Press release. Retrieved September 3, 2018, from http://www.gartner.com/newsroom/id/3270418
- GfK. (2016). Global smartphone sales growth driven by China. Press release. Retrieved September 2, 2018, from http://www.gfk.com/fileadmin/user_upload/dyna_content/Global/documents/Press_Rel eases/2016/20160519_GfK_global_smartphone_release_Q12016_vfinal.pdf
- Goluchowicz, K., & Blind, K. (2011). Identification of future fields of standardisation: an explorative application of the Delphi methodology. *Technological forecasting and Social change* 78, 1526 1541.
- Green Alliance. (2015). A circular economy for smart devices : Opportunities in the US, UK and India. London, UK: Green Alliance.
- Groopman, J. (2014). *Interoperability: the Challenge facing the Internet of Things*. ALtimeter Group.
- Guenveur, L. (2017). An Incredible Decade for the Smartphone: What's next? The Future of Mobile is in Combining Devices, Content and Services. Kantar World Panel.
- Guide, V., & Van Wassenhove, L. (2009). OR FORUM The Evolution of closed-loop supply chain research. *Operations Research i*, *57*(*1*), 10-18.
- Guide, V., Souza, G., Van Wassenhove, L., & Blackburn, J. (2006). Time value of commercial product returns. *Management Science* 52, 1200-1214.
- Hagelüken, C. (2008). Opportunities & Challenges to Recover Scarce and Valuable Metals from Electronic Devices Electronics Contain up to 60 Elements – a Complex Mix of Valuables & Hazards. OECD - UNEP Conference on Reosurce Efficiency. Paris.
- Harms, R., & Linton, J. (2015). Willingness to Pay for Eco-Certified Refurbished Products: The Effects of Environmental Attitudes and Knowledge. *Journal of Industrial Ecology, 20, Issue 4*, 893-904.
- Hazen, B., Overstreet, R., Jones-Farmer, L., & Field, H. (2012). The role of ambiguity tolerance in consumer perception of remanufactured products. *International Journal of Product Economics 132, Issue 2*, 781-790.
- Hong, X., Govindan, K., Xu, L., & Du, P. (2017). Quantity and collection decisions in a closedloop supply chain with technology licensing. *European Journal of Operational Research 256*, 820-829.
- Huang, Y., & Wang, Z. (2017). Closed-loop supply chain models with product take-back and hybrid remanufacturing under technology licensing. *Journal of Cleaner Production* 142, 3917-3927.
- Humphries, M. (2010). Rare Earth Elements: The Global Supply Chain. *Congressional Research Service Report*.
- Iacovidou, E., Millward-Hopkins, J., Busch, J., Purnell, P., Velis, C., Hahladakis, J., . . . Brown, A. (2017). A pathway to circular economy : Developing a conceptual framework for compex value assessment f resources recovered from waste. *Journal of Cleaner Production 168*, 1279-1288.

- IBM. (2015). *Device Democracy: Saving the future of the Internet of Things*. IBM for Business Value.
- Islam, M., & Huda, N. (2018). Reverse logistics and closed-loop supply chain of Waste Electrical and Electronic Equipment (WEEE)/E-waste: A comprehensive literature review. *Resources, Conservation & Recycling 137*, 48-75.
- Kirchherr, J., Hekkert, M., Bour, R., Huibrechtse-Truijens, A., Kostense-Smit, E., & Muller, J. (2017). *Breaking The Barriers to the Circular Economy*. Utrecht: Deloitte ; The Copernicus Institut of Sustainable Development ; Utrecht University .
- Lee, T., Chang, H., & Chen, S. (2007). An investigation of perception gap of reverse logistics service quality: the case of mobile phone industry. *International Journal of Global Environmental Issue*, 7 (1), 25-52.
- Matsumodo, M., & Umeda, Y. (2011). An Analysis of remanufacturing practices in Japan. *Journal of Remanufacturing*, 1 (2), 1-12.
- Mazhar, M., Kara, S., & Kaebernick, H. (2007). Remaining life estimation of used components in consumer products: Life cycle data analysis by Weibull and artificial neural networs. *Journal of Operations Managemen 25* (6), 1184-1193.
- McKinsey & Company. (2015). The Internet of Things: Mapping the Value beyond the hype. Mc Kinsey.
- Mugge, R., Jockin, B., & Bocken, N. (2017). How to sell refurbished smartphones? An investigation of different customer groups and appropriate incentives. *Journal of Cleaner Production* 147, 284 - 296.
- OECD. (2012). Perspectives on Global Development 2012, Social cohesion in a shifting world.
- Rathore, P., Kota, S., & Chakrabarti, A. (2011). Sustainability through remanufacturing in India: a case study on mobile handsets. *Journal of Cleaner Production, Vol. 19*, 1709-1722.
- Ritzén, R., & Sandström, G. (2017). Barriers to the Circular Economy integration of perspectives and domains. *The 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems*. Stockolm: Elsevier B. V.
- Rogers, D., & Tibben-Lembke, R. (1998). Going Backwards: Reverse logistics trends and practices. *Reverse Logistics Executive Council*. Reno: Center for Logistics Management, University of Nevada.
- Roland Geyer, V. D. (2010). The Economics of cell phone reuse and recycling. *International Journal of Advanced Manufacturing Technology*, Volume 47, pp 515-525.
- Souchet, F., Meloni, M., & Sturges, D. (2017). Your Circular Electronic Product Must Have These Three Features. *circulatenews.org*. Retrieved August 14, 2018, from https://circulatenews.org/2017/12/circular-electronic-product-must-three-features/
- Stageman, H. (2008). *The potential of the Circular Economy*. Utrecht: Rabobank/RaboResearch.
- Stahel, W. (1981). *Jobs for Tomorrow, the Potential for Substituting Manpower for Energy*. New York: Vantage Press.
- Stahel, W. (2006). The Performance Economy. PALGRAVE MACMILLAN.

- Storm-Mathisen, A., & Slettemeås, D. (2016). Dematerialisering gjennom digitalisering og teknologisk konvergens? *Strandbakken, Forbruk og det grønne skiftet*. Oslo.
- Taffel, S. (2012). Escaping attention: Digital media hardware, materiality and ecological cost. *Culture Machine*, *3*, 1-28.
- Tan, Q., Dong, Q., Liu, L., Song, Q., Liang, Y., & Li, J. (2017). Potential recycling availability and capacity assessment on typical metals in waste mobile phones: a currentresearch study in China. *Journal of Cleaner Production 148*, 509-517.
- Umair, S. B. (2013). Social life cycle inventory and impactassessment of informal recycling of electronic ICT, waste in Pakistan. Proceedings of the FirstInternational Conference on Information and Communication Technologies forSustainability. ETH, Zurich, pp. 52– 58.
- UNEP. (2011). *Recycling Rates of Metals A status Report*. United Nations Environment Programme.
- UNEP. (2013). *Metal Recycling: Opportunities Limits, Infrastructure*. United Nations Environment Programme.
- van Eijk, F. (2015). Barriers & Drivers towarda a Circular Economy. Naarden: Accelleratio.
- Van Wassenhove, L., & Zikopoulos, C. (2010). On the effect of quality overestimation in remanufacturing . *Journal of Production Research*, 48 (18), 5263-5280.
- van Weelden, E., Mugge, R., & Bakker, C. (2016). Paving the way towards circular consumption: exploring consumer acceptance of refurbished mobile phones in the Dutch market. *Journal of Cleaner Production 113*, 743-754.
- Vitasek, K., Manrodt, K., & Ledyard, M. (2013). Going the Whole Nine Yards : The Dell-Genco ATC Vested Journey. In K. Vitasek, K. Manrodt, & M. Ledyard, Vested Outsourcing - Five rules that will transform Outsourcing (pp. 185-199). New York: Palgrave MacMillan.
- Wang, Y., & Haxen, B. (2016). Consumer product knowledge and intention to purchase remanufactured products. *International Journal of Production Economics*, 181, Part B, 460-469.
- Watson, D., Gylling, A., Tojo, N., Throne-Holst, H., Bauer, B., & Milios, L. (2017). Circular Business Models in the Mobile Phone Indstry. Copenhagen: Nordic Council of Ministers.
- Wilson, G., Smalley, G., Suckilng, J., Lilley, D., Lee, J., & Mawle, R. (2017). The hibernating mobile phone: Dead storage as a barrier to efficient electronic waste recovery. *Waste Management* 60, 521 - 533.

Index of figures

```
Figure 1.1 Accenture (2014), Accenture analysis based on data from World Bank, Commodity
Price Data (The Pink Sheet), April 2014 version..... Errore. Il segnalibro non è definito.
Figure 1.2 Estimated depletion over time of the main industrial materials and recycling rates at
2013. Source: Professor James Clark, Green Chemistry, The University of York (Clark & Hunt,
Figure 1.3 Towards the Circular Economy Vol. 1: an economic and business rationale for an
Figure 1.4 Interactions of circular Economy and Intelligent Asset value drivers with the
relevant opportunities of value creation; Ellen McArthur Foundation (2016); Intelligent
Figure 1.5 Hierarchies in Waste Management according to the European "Waste Frmework
Directive" 2009/98/EC: Extracted in: http://ec.europa.eu/environment/waste/framework/...... 32
Figure 2.1 A basic overview of a Closed-Loop supply chain that joins Forward and Reverse
Logistics. It appears the critical importance of a "central brain" - in this case is called a return
processor – that processes the returns and judges their conditions and destinations along the
various possibilities that increases their value yield over time. This is an adaptation from a
model conceived by Chopra and Meindl (2010).....Errore. Il segnalibro non è definito.
Figure 2.3 Design of product lifecycles and reusing strategies for product reusing as a core
Figure 2.4 A chain of decision to be taken by managers to decide the CLSC strategy to put in
Figure 3.1 Aggregated global data on collection and recycling rates of E-waste in 2016. (Baldé,
Figure 3.2 Potential value of raw materials in e-waste in 2016, (BALDÉ, FORTI, KUHER, &
Figure 3.3 Overview of the Fairphone official shop for spare components. Available at:
```

Resume of the Contents

1. The Circular Economy and the Circular Industrial Model: Exploring a new Framework

Circular Economy is a restorative industrial model, where products are designed and intended to be readily reused or disassembled to be, at that point, either easily refurbished or recycled. The difference is remarkable: within the circular economy framework the reuse of materials and their residual utility along several industrial cycles– at a product, component or material level – is the foundation of the economic growth. Since the framework goal is minimizing new input to the value chains, unlimited resources like labour and renewable energy sources take a central role while resources characterized by natural supply limitations are reserved more of a secondary and supporting role.

The Circular Economy can be defined as opposed to the actual "take-make-dispose linear industrial model. As long as the overall industrial model is based on one-way resource consumption, though the efficiency can be improved on single components of the chain, it will generate long term and aggregated losses. The new century price increases - being 1,9% price index increase for each 1% growth in GDP- spread light to the wasteful waste management systems and the rise in prices' volatility made hedging contracts more expensive. Another factor is that the global middle class, along with their consumption preferences, is expected to more than double by 2030. Much of that change will be coming from developing countries and will bring up to USD 30 trillion yearly of more demand. There are a lot of pessimistic projections on the demand for limited resources (Biomass, fossils, energy and some metals) ranging, by 2050, between 200% and 400% the earth annual capacity. While some even predict the total depletion of the natural capital with respects to some precious and strategic metals for many industries. Moreover, before fiscal regimes started to predict indirect costs associated with energy and some materials, the biggest efficiency gains consisted in substituting the labour costs with more resources, like energy. With respect to the latter, the majority of costs and energy usage usually take place in the upstream level of the supply chains, at the extraction stages. Within this view, the Circular Industrial model aims at decoupling the sales revenue from material inputs or new resources extraction.

School of thoughts. The Circular Economy framework has many theoretical roots in the last 50 years. Most of them deal with a systemic view of the industrial environment that inspires to nature as a biological cycle (Biological/Industrial metabolism, Regenerative design, Industrial Ecology, Biomimicry). McDonough and Braungart, fathers of the "cradle-to-cradle" approach, started to see the industrial process more as a material flow of biological and technical "nutrients". While the former should continue a cicle by building natural capital, the latter should be designed to express all its potential utility in the biosphere but without entering it. A technical nutrient entering and remaining in the biosphere is a loss – especially if some residual value is sill present. That is why, and this is one key building block of the framework, waste should be designed out of a product concept. A material cycle should be put in place out of each product, where design helps retain as much value as possible through easy disassembly, refurbishing or, eventually, recycling. In 2015, the British minister for food and rural affairs estimated that each pound invested in Eco-design generates 3,8 pounds in earnings for the economy.

Functional Service Economy. Others, like Walter Stahel predicted that the evolving industrial system at the end of the 70s was not compatible with a globalised future with finite resources. Since a systemic approach is essential, one-way consumption appears as one key barrier for the economy to get circular. In a "functional service economy" the ownership of the asset/products is shared: manufactuers/retailers switch towards being service-providers, while consumers become users. The resource security risk can be tackled down once the resources that have been already deployed can be used again, with the only boundary of an "extended performance responsibility" over what the users obtain in terms of service: the result would be a sort of "lake economy" that is, within the physical limits, self-sufficient and loops on itself. Michelin pioneered in this field with its 1920 pay-per-kilometre program, retaining the ownership of the tyre in order to collect them to either extend their life or recycle them. Other examples come from General Electric and Philips's light-as-a-service.

The main circular activities. "Cascades" of products/components/materials is the process of prioritising the highest value activity that better exploits the residual utility of a product. As the items go through a cascading process their material order or utility/quality of their components decreases. Goods or components that can be reused should be either maintained and given back to the consumer or looped back to the

distributor, sold on secondary-markets or redistributed as lower-end products. As more activities are required the loops gets bigger also with respect to transportation and operational costs. Other goods would need refurbishment processes implying a general check-up of the components to be either repaired or replaced together with aesthetic regeneration. When the majority of a product is faulty, remanufacturing consists in draw out what still holds residual value/utility and insert it into new products or other refurbished ones. The market for remanufactured products has been estimated to be $1.5 \in$ trillion in 2015. The loop gets even bigger for the products or the spare parts of the abovementioned processes that need to undergo recycling processes that either produce materials of reduced quality and functionalities, namely "downcycling", or increase those two parameters, namely "upcycling". Finally, the unrecoverable waste that is forced out is the framework's enemy. Energy recover can be converted into heat, electricity or fuel. It is not a desirable option but it is better than the landfilling disposal which is a complete loss of economic and physical value though still represent a common global practice.

Sources of circular value. According to Ellen MacArthur Foundation, the main sources of economic value are four. The first is that the stricter the loops, the larger the transportation, material, labour and capital savings. The second is that increasing the life-cycle of the products through durable materials and refurbishing processes reduces the virgin material inflows. The time efficiency of the loop is essential, especially with products that have high innovation rates. The third is that products can be cascaded also towards different product categories or even markets, as long as the commercial utility is exploited. The fourth regards easy-to-separate product design and material purity as a way to facilitate any downward circular practice. The effects would be to reduce the costs of the reverse cycles and to reduce components/materials longevity and productivity.

Circular Economy's enablers. The main enablers of Circular Economy would be technology, legislations while culture holds two-folded considerations. The intensity and quality of the informational flow that are continuously spilled by the huge amount of intelligent assets can solve many pragmatic challenges connected with circular economy, such as the ones connected with reverse logistics. Location and availability of the asset together with its conditions – assessed towards intelligent predictive maintenance – and compositions – the product passport can increase the traceability of the materials/components in each device. In addition, especially at a European level, many

steps are being taken since the "Waste framework directive" (2008/98/EC) and the "Ecodesign Directive" (2009/125/EC). Innovative concepts such as "extended producer responsibility" and "polluter pays principle" have been introduced, though with weak adoption of the members. Moreover a "hierarchy" in the waste management practice has been establish, reflecting the above-mentioned concept of cascades. European union has drafted an ambitious set of measures actions and targets covering the whole life-cycle, from production to post-consumption waste, called "Closing the loop – an EU action plan for the Circular Economy". With respect to culture, the diffusion of Sharing Economy aspects can increase the adoption of circular economy aspects – as the people can et used to access rather than possess an asset – while barriers within the firms' boundaries and in the consumers towards, for example, refurbished/remanufactured items remain.

2. Reverse Logistics and Looping Supply Chains: an overview

Some manufacturers are starting to look at reverse logistics activities as a business opportunity rather than just a cost-minimisation approach or an environmental initiative to be advertised in Corporate Responsibility Reports. Conversely to the conventional forward approach to Logistics and – especially – supply chain, Reverse Logistics is the process of implementing and controlling the cost effective and efficient flow of raw materials, finished goods and information from either the costumer itself or the point of consumption to the point of origin, being the manufacturer or the retailer, with the aim of minimising the losses of value by recapturing it. The result of joining a classical forward supply chain with a reverse one creates what has been many times evocated as "Closed Loop" supply chain. It pursues the aim of achieving some form of reuse or reclamation of either products or materials. Different decisions may be taken regarding the objective of Reverse Logistics, from recycling, to remanufacturing, repairing and – eventually – disposing of some parts/components. As the returns are collected at the beginning, activities appear hierarchized based on their value potential through multiple lifecycle. It is the operational translation of the above-mentioned concept of "cascade". Physical, chemical and economic value is retrieved the if products or component reprocessing, through refurbishing or remanufacturing, are performed before considering a material reprocessing, a process that consist in the material recovery through recycling activities and even requires more energy. In addition, as shown in the above figure, it appears physically inevitable to have some kind of end-of-life waste streams. Some products, components or, lastly, materials have a limited or even single number of life cycles. It is a task of major importance for supply chain managers to identify channels for their waste streams that can translate into profitable opportunities.Products returning back from the consumption stage can be either end-of-use, usually large industrial machineries which have been extensively used, and "false failures", typical of consumer products and sometimes results of an arbitrary decision.

Main CLSC activities. CCLSC strategies can be divided in: (1) front-end activities are aimed at collecting back the products, the location of the collection facilities is crucial; (2) Engine activities entail technical feasibility and market analysis (design, material composition, market acceptability and operational issues). Then the items are processed following directive on their highest value destination, namely refurbishing, remanufacturing or recycling; (3) Back-end activities entail marketing the product again for another lifecycle. The main risks are consumer acceptance (20/30% would not considered used products/components), brand consequences and cannibalization (some manufacturers sell remanufactured products through other channels).

Marginal value of time. In addition, it must be taken into account the marginal value of time pressure that a product/component may have with respect to its destination market is critical, especially in technological/innovative sectors. The cost of performing activities such as acquiring, testing, inspecting and returning the product is correlated with their quickness, while the costs of the delay may vary between industries and product lines. As an industry gets more mature and the pace of innovation slows down, is where a firm should start getting to now and considering putting in place CLSC strategies to increase profit opportunities

Design strategies vs core competencies in Reverse logistics. Operational requirements of reuse processes requires important investments in remanufacturing capabilities with respect to both capital and human resources, thus decisions on whether to put in place reverse logistics and transportation networks in-house or outsourced, should also be based on the degree of core competences that a firm possess or could be able to achieve. Along the dimensions of design and core competencies, four strategies can be distinguished. (1)

Robust design but no core competencies in reusing strategies: post-sale support is limited and no interest in reacquiring assets. The downside is the empty space left to third-party industries to grow and seize the remanufacturing opportunity. The example ocmes from airline sector where major players left third parties specialise and gain competitive advantage. (2) Robust design and reusing as a core competence: the manufacturers focus on generating as many product lifecycles as possible in order to maximise the total lifecycles profits, therefore strong vertical integration is needed at the initial sale and reacquisition stages. If not vertically integrated, the strategy will end up favouring third parties. (3) Single lifecycle: design and no core competence in reusing. Used in fast moving ndustries. Strong focus on maximising profits through resource efficient designs and manufacturing systems. (4) Third-party reuse: robust design but no core competences in reusing strategies. The third-party re-use is a direct consequence of the fact that an original equipment manufacturer considers product/component/material level reuse as a non-core competence. When this happens at a product level, by letting third-parties free to remanufacture, the original manufacturer has created all the precedents for creating/attracting a competitor in its own market space and that uses its own products/components.

Consumer and remanufactured products. The reaction of consumers to remanufactured products can be twisting. If the remanufactured items coming from the original manufacturers have negative effects on perceived value, still the original manufacturers could benefit from having remanufactured products under a different brand. This would mean outsourcing just the final sell of the remanufactured products. Original manufactures can put in place measures to limit the negative effects on perceived value correlated with the presence of remanufactured products (geographic or market-channel discrimination).

Corporate strategies and Closed-loop Supply Chain. With respect to Closed-loop supply chain strategies, third party involvement appear to be a strategic choice that can be both profitable and functional, especially when core-competencies does not make the original manufacturer able to seize the proper amount of residual value. Vertically integrated CLSC strategies have the control as the main strategic objective. There are procurements problem with respect to bulk buying activities, optimal capacity and production planning and cannibalization risks. Outsourcing CLSC strategies, using not

only the contractual obligation but also by imposing intellectual property barriers on components and design, if possessed can be complex if the degree of outsourced activity is total. A downside of a fully outsourced strategy is the total or at least partial loss of precious insights on design flaws and the related improvement opportunities they entail. Moreover, contracted reverse logistics and especially reuse/remanufacturing partners usually are not endowed with great competencies in commercialising the products back to the market. Hybrid CLSC strategies are what the majority of firms actually put in place. The main risks is in assessing the core competences possessed and which one are not easily developable. Design specifications should be retained in house. Risks connected with intellectual property, pricing contracts and the loss of control over the CLSC system. There are no one-size-fits-all approaches. It must be noted how fully vertical approaches to CLSC are rare and small in absolute numbers. The trend observed by Abbey and Guide (2017 is that on one hand, forward supply chain keeps being outsourced – in line with the overall tendency of many industries towards decentralisation, one of the consequences of Open innovation framework and the diffusion of the market for technology -, on the other hand, in-sourcing remanufacturing activities is being always more difficult. As mentioned before, once a forward supply chain and the related manufacturing activities are outsourced, usually also the remanufacturing ones follow the same path.

The key strategic take-home is that third parties' activities – or potential future ones – shall not be ignored, since other players could enter and compete the manufacturers in the very same market with or without their consensus. In that, Dell's strategy has been proved to be superior since, even though all the reverse logistics has been outsourced, some kind of contractual control has been retained and, in turn, value has been extracted. Because of these knowledge, scale and specialisation economies, it can be stated that, once an industry cedes control over remanufacturing activities and leave it free to be seized by third parties, regaining that control over again once the market has been recognised and it is growing can be difficult and costly.

3. A circular Industrial model for Consumer Electronics

From a product point of view, design strategies that aim at modularisation and standardisation can ease the adoption of circular practices. From a technological point of view, switch to a dematerialised and virtualised cloud computing infrastructure can decrease the demand on devices' performance, making them simple interfaces hat can therefore be used for longer due to a lower wearing.

WEEE. Items such as smartphones, computers and wearable equipment, though composed by durable and valuable materials, are subject to relevant losses of value and resources because of the above-mentioned mainstream disposable practices. By the term "Electronic waste" or "E-Waste", we refer all the items of electrical and electronic equipment (EEE) and its parts that have been discarded without conceiving any "cascade" activities that would further express their residual utility and/or value. Trends causing the e-waste generation to increase (44.7 million tonnes) are the multiple device ownership, electrifying tendency of the market and shorter replacement cycles. The loss of value estimated was 55€bln in 2016 due to the presence of precious metals. The value alone of the wasted mobile phones was estimated to be 9.4 billion Euro in 2016, they could become an important secondary source for precious metals like silver, gold and other metals with industrial aplications such as Copper, Nickel and Zinc. Within a mobile phone archtecture, it has been identified that the the components that would be more adapt to be subjects to circular practices would be the camera, the display, the printed wire boards, the battery and the charger; being the most valuable parts and easiest to disassemble.

Circular Economy represents a vision and a workable path forward to rethink the system of the EEE industry and take it away from the Linear Industrial Model of the "take-makedispose" paradigm. The strategies will, naturally, have to recall the different kind of loops we have identified in the first chapter while analysing the general Circular Economy framework.

Reverse logistics and EEE. When it comes to put in practice activities aiming at closing the loop with electronic devices and, generally, WEEE, there are other factors such as

quality, quantity and time involved. The most immediate factor of complexity is that those streams coes mainly from three different sources: households, institutions and businesses. The collected back resources have to be transported to treatment facilities to be tested, disassembled inspected, sorted and then according to specific product/component/material categories. Another factor of complexity is the difficulty of estimating which is the best available strategies to exploit what has been collected, depending upon the material content, its ease of disassembly and/or extracting components and the purity of the materials. The key parameters in the performance of EEE reverse logistics that appeared as the most incisive on reverse logistics performance were the returned amount (27%), the quality (17%) and cost, prices, time and demand at 7%. In putting in place a reverse logistic system which is focused towards remanufacturing activities, it has been found that the location of treatment facilities and estimation of residual value are the key performance indicator in designing a whole looping supply chain. Some key principles about reverse logistics have been coupled with the remarkable challenges posed by the very nature of their objects when it comes to electrical and electronic devices. Architectural complexity, quality of materials, retuned items destination, location of the Reverse Logistics facilities are huge points of marks when it comes to close the loop in a supply chain. From an intellectual property point of view, remanufacturing activities would need a manufacturer's patent licensing approval in order to make use of the components which are covered by patent protection. For example, Apple has recently subcontracted Foxconn to embrace remanufacturing activities in China with respect to End-Of-Life I-phones.

Design. As outlined in the first chapter, many problematics connected with Circular Economy implementation can be addressed at the design stage. Design strategies need to be formulated starting from the specific approach that has been chosen to maximise the utility of a product in terms of time, performance, End-of-life uses and customer satisfaction in static/dynamic markets. (1) Design for Durability can be achieved both at the architectural level, making the product and the connections between components last longer, and at a component level, whose durability should not vary with respect to the rest of the product. This strategy does not cover exclusively the technical/performance aspects of a good, what has been defined "emotional durability" or "emotional design". This kind

of strategy is more suitable for markets that are more static both in terms of consumer preferences and pace of the innovation. (2) Design for Maintenance and repair either by a technician or the user. A device can be kept in use for longer through a design that is maintenance and repair friendly for both the technician – cost time balance – and the user – risk of compromising the performance. The strategy should achieve the ease of product inspection, product replacement and availability of spare components. (3) Design for adaptability and upgradability. Through modular designs, manufacturers should make it possible to adapt or enhance some functions to match new user requirements without the need of marketing other new devices. (4) Design for refurbishment and/or remanufacturing: a technician or a third company should be able to restore the performance of the product to its initial original working condition either by refurbishing a part of it or by remanufacture the whole device with cost effective processes.

Moreover: materials should be chosen to fit as many cycles as possible and be readily recycled if needed. The material bill complexity should be limited and trackable, e.g. through product passports. And finally, software compatibility should be ensured to enable and improve the hardware longevity.

It has been deducted - along with designers, repairers and recyclers that have been interviewed – that a way forward could be a partial disassembly that has the pros of fostering (I) an ease of repairing the main components of a device and (II) substitute them in case of refurbishment activities (as well as (III) increase the operational and economic effectiveness of the recycling process in terms of material recovery yields.

Standardisation. As the costs of embracing circular practice to finally be able to "close the loop" might appear remarkable, establishment of industry standards can create the right alignment of incentives to better establish cross-chain and cross-sectoral collaborations. In addition, standardising components across models or even brands can increase the ratio for adopting collection systems as the costs of a more standardised process will be more justified by higher yields. Standardised architectures or components could make it easier and economically rationale to invest in developing processes that increase the automation and therefore the yield in terms of products processed.

Interesting is how the widespread importance of cloud computing might be a big driver in changing the demand for greater storage and computing capacities in our devices. As the information are not stored in our devices, their processing can happen remotely and processing power and data storage demand are taken away from the devices. Further research should be performed on the willingness to abandon ownership of devices as they become a mere access portal towards their dematerialised digital assets.

User perception. There is a theme of user perception when it comes to used and/or refurbished electronic devices. As the degree of technological innovation increases, refurbished electronic devices still find the majority of consumers cautious. The main problems is the awareness of refurbishing process, the performance risk and the financial one. Solutions might be: adding additional services, tackle the informational gap, adding product-related enhancements, highlighting the environmental mission.Consumers are different in their attitudes towards consumption of electronic devices. Big data and advanced analytics can increase the yield of a matching exercise to supply different customer segments exactly their desired function and, at the same time, organise efficient and predictive reverse logistic in order to migrate the devices towards less exigent consumers. Within this view the cascading processes can take place also between different consumers, as the potential utility and performance of the device – or its components/main architecture – decrease.

Smartphones. After steep and increasing global selling rates, penetration of new models is slowing down – especially in wealthy economies. If the market has made the average consumer used to continuous innovations and "killing" new features, the most common reason for replacing the device is owning the newer model. Here is why, especially in developed countries, the slowing down of new smartphones sells can be explained by the fact that most people already possess a sophisticated and powerful device and now the innovation model makes the technological changes from one model to the other being more incremental than disruptive. As a consequence, secondary markets for smartphones are growing. The worldwide market for second-hand or refurbished phones is expected to reach 120 milion units by 2017. Original Equipment Manufacturers will need to look into the secondary market for phones and formulate strategies to turn these phenomena in

an opportunity for their businesses. The main players are the producers, the electronic retailers, network device providers, repairers and second-hand sellers and refurbishers. Right now, most of circular business models within the industry entail take-back and buyback programs. With respect to phone carriers, it is remarkable the observed tendency of customers towards sim-only plans paired with a spreading rejection of bundled phone and services offers. Moreover, Upgrade Programmes" give the customer given the chance to replace their phone with the new model, without needing to finish off the rates to obtain its full ownership of the old one. Once a device is taken back and – maybe – refurbished, they can be either given back to the same market segments it has been drained from or cascaded back in terms of market segments – directing it towards other less demanding customers – or geographically, towards developing countries.

Fairphone 2. The design strategy started from identifying the factors that push people to replace their smartphones. It is the first fully modular smartphone that is designed to be durable and easily disassembled, upgraded and recycled. In contrast with the industry's tendency to seal up all the components, in the sake of a device minimised thickness, Fairphone decided to reinvent an architecture that make it easier to perform assembly and disassembly services. Most of the maintenance can be performed by using just a screwdriver, allowing anyone with a screwdriver to restore its functionalities or even upgrade new ones. Within the same architectural regime, space was left to let the users introduce themselves new features like NFC and wireless charging. In addition, 2 years later the dutch company made it possible to upgrade the device camera through an easy component substitution.

Strategic approaches towards circularity within the smartphone industry. What if the access to smartphones were given on a leasing-based business model and cascaded down, at a component-level, through less exigent customer segments along several time-slots before being ultimately either recovered – at a material-level – or sold in the secondary market? As the marginal value of our smartphone is decreasing, it is time to switch the industrial approach towards the business that is made out of our devices. The smartphones out in the market should remain a manufacturer's asset and their management should be outsourced to an ecosystem of service providers that take care of

the reverse logistics activities. Those reverse logistic activities should achieve the right balance between cost and time efficiency and at the same time having a smooth service as a minimum requirement. Reusing operations, may those be refurbishing or architectural remanufacturing, should be better done at the distribution facilities rather than in the retailer shops. Therefore, we would be avoiding doubling the costs of transportation and logistics towards the pre-existing channels. The flows of devices to be - some more, some less - reprocessed should be discriminated upward. Within this view, predictive maintenance appears to be potentially the key towards achieving such complex systemic approaches in a manner that is perceived as smooth by the consumers/users. As we have mentioned time-slots, similar to the upgrade programmes that had been promoted by the phone-carriers companies at a retail level, the predictive potential of a Closed-loop supply chain is essential to either anticipate any disruption in the usage – that, being service-based, should be guaranteed and as smooth as possible – but also to gain technical insights that somehow help design, procurement and engineering planning of the wearing and performance patterns along those slots. At the same time, decentralised in as many aspects as possible to smooth the service up and decrease the costs that, as we mentioned, are well influenced by transportation and facilities' location. Decentralisation should be achieved upward. In this model the ownership of the asset is retained though, implying that no user would have an incentive to operate "pirate" or not-authorised task of any type because of the risk of undergoing some penalties. Double-folded effect of modular design: skill, capital and labour exigencies would be tackled down on one hand, users could be rewarded to perform the repair, substitution and upgrade activities themselves. In addition, "expert customer group" are always wanting the newest model and, from a cascading point of view, they will get it. Each time they return their to get a new one, their old devices' components will undergo reverse logistics process and be refurbished into a second lower-end group of devices. This is potentially a multi-stage business model in which components could be cascaded down towards less exigent and more pricesensitive market segments.

On the basic idea of Stahel's "lake economy", a pool of resources circulating between different type of users and refurbishing facilities could be the way forward into the smartphone industry. In addition, the idea that some ordinary tasks could be delegated even to users that are willing with zeroed transaction costs and payment through credits and discounts on the service is interesting and worth of further research. What if remanufacturing were made so easy it could be "out-sourced" to users?

In conclusions, advancements of the industry towards circularity can be ignited by both design strategies and investments towards establishing Closed-loop supply chain that make it possible – if accompanied by contractual forms that imply either take back incentives or products as a services schemes– to perform a control of the assets' lifecycles in order to smooth up the perception of such services, its operational efficiency and the profitability over time – at the product, component and material level – of each asset that is immitted into the market.