D 2.1
Pathways instantiation from DT-ICT-07 domains- First Iteration

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[1] PU: Public, CO: Confidential, only for members of the consortium (including the Commission Services)
[2] RE: Report, OT: Other; ORDP: Open Research Data Pilot

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Abbreviations and acronyms

TERMS, ABBREVIATIONS AND ACRONYMS	
CA	Consortium agreement
CO	Coordinator
DoA	Description of Action
DPO	Data Protection Officer
EB	Executive Board
EC	European Commission
GA	Grant Agreement / General Assembly
ORDP	Open Research Data Pilot
QM	Quality Manager
QMP	Quality Management Plan
SyGMa	System for Grant Management
WP	Work package
WPL	Work Package Leader

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Executive Summary

The present deliverable aims to instantiate the Circular Economy pathway within the four domains of the DT-ICT-07 (i.e. (1) Agile Value Networks: lot-size one, (2) Excellence in manufacturing: zero-defect processes and products, (3) The human factor: human competences in synergy with technological progress, (4) Sustainable Value Networks: manufacturing in a circular economy) among which the DMP cluster was born. Across these four domains different projects have been developed among which "eFactory[3]. European Connected Factory Platform for Agile Manufacturing" for the "Agile Value Networks: lot-size one" domain, for the second domain, "Excellence in manufacturing: zero-defect processes and products", the related projects are "ZDMP[4]. Zero Defect Manufacturing Platform" and "*QU4LITY Digital Reality in Zero Defect Manufacturing",* for the third domain, "The human factor: human competences in synergy with technological progress", the related project is "SHOP4CF[5] Smart Human Oriented Platform for Connected Factories", and last for the fourth domain, "Sustainable Value Networks: manufacturing in a circular economy**"**, the projects are "DigiPrime Digital Platform for Circular Economy in Cross-sectorial Sustainable Value Networks", and "KYKLOS 4.0[6] An Advanced Circular and Agile Manufacturing Ecosystem based on rapid reconfigurable manufacturing process and individualized consumer preferences".

Actually, these projects aim to address the challenges that the manufacturing sector is currently experiencing. In particular, the European Commission has designed an Industrial Strategy to guide the manufacturing sector towards a sustainable development being helped by the current digitalisation of factories. Moreover, if we look at the European scenario, we can see that there are around 25millions SMEs characterising the economy or our countries and they can all stimulate innovation in the great challenges and objectives already mentioned among which the climate neutrality and social cohesiveness allowing to address the European Industrial Strategy. This strategy requires to address all the needs coming from the different panel of European SMEs that are of various types in terms of business models, size, age, and entrepreneurs' profiles involving both women and men. In particular, three main pillars guide this strategy with the intention to lead a successful twin transition:

- Capacity-building and support for the transition to sustainability and digitalisation;
- Reducing regulatory burden and improving market access;
- Improving access to financing.

As already mentioned, the competitiveness of enterprises nowadays needs to take into account not only the economic sustainable pillar but also the social and environmental ones. Therefore, to support enterprises in this direction, the European Commission proposed the European Green Deal A European Green Deal | European Commission (europa.eu) which provides an action plan devoted to:

- Sustain the transition towards more clean and circular economy relying on the efficient use of resources
- Reduce at minimum pollution and restore the biodiversity

[3] https://www.efactory-project.eu/
[4] https://www.zdmp.eu/
[5] https://www.shop4cf.eu/
[6] https://kyklos40project.eu/

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Therefore, to achieve these goals new innovative solutions need to be developed and financial incentives must be defined. Among all, Circular Economy paradigm is one of the main elements of the European Green Deal since it can represent a great solution towards climate neutrality and efficient use of resources. Actually, its adoption can be highly facilitated by the introduction of different digital technologies as reported in the document developed by the European Policy Centre named "A digital roadmap for a circular economy".

Four key elements must be respected to obtain the expected goals:

- *Define a vision and act accordingly* to make Europe become leader is utilising data and digitally-enable solutions and to extend the product lifecycle by being supported by the synergies among the digital and sustainable solutions,
- *Use governance, policies and regulations to provide a framework for action* by allowing the data and information sharing and access, providing digitally-enabled services, improving the e-commerce and the eco-design.
- *Use economic instruments to encourage and enable the transition* by introducing the right financial tools, by supporting the reskilling and upskilling of the workforce and by directing the investment.
- *Strengthen partnerships and empower citizens* by relying on the usage of the already existing stakeholders' platforms, by underlying the benefits for data exchange increasing the trust in their relationships.

Although the benefits are well known, manufacturers need to be guided in this direction and for this reason a tool has been developed within the work performed by the Circular Economy pathway. This tool is a maturity assessment model based on 5 levels of maturity and 6 dimensions allowing manufacturers to undertake this transition in a more aware and structured way after a deep analysis of their current status. These dimensions cover both the technical and the social aspects to ensure to have a big and complete picture of the company interested in undertaking the path.

This tool has been tested though a series of workshops involving practitioners from other projects, such as BOOST4.0. Thanks to MURAL, a collaborative tool, it was possible to create interactive sections to gather feedbacks and improve the tool that has been mainly based on scientific knowledge.

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1 Introduction

The introductive chapter aims to first clarify the objective of the deliverable, second to elucidate the structure of the deliverable in order to clearly address the objective, third to show the main links that are present among the activities and pathways characterising the CF1 and CF2 projects and last, to create the ground to explain the activities performed by the DMP cluster.

The objective of the deliverable is to provide an overview on the CF2 achievements in terms of the pathways developed throughout the ConnectedFactories II project. Indeed, the deliverable D2.1. is the first deliverable of WP2 and, more precisely the D2.1 is associated to the task T2.1. This deliverable aims to elucidate the work performed around the concept of Circular Economy to instantiate this pathway in the four domains of DT-ICT-07 which are: 1) Agile Value Network, 2) Zero Defect manufacturing, 3) Human Factor, 4) Sustainable Value Chains. Indeed, starting from the achievement from the previous project, ConnectedFactories in which three main pathways have been detected (i.e. Smart Autonomous, Hyper-connected and Collaborative Product-services Factories), in this project other two have been individualised to pursue the work and improving it.

The structure of the deliverable is elucidated as follows.

- In chapter 1, it is first reported a brief introduction regarding the context in which the project has been put in place. To be more precise, the four domains of the DT-ICT-07 (i.e. (1) Agile Value Networks: lot-size one, (2) Excellence in manufacturing: zero-defect processes and products, (3) The human factor: human competences in synergy with technological progress, (4) Sustainable Value Networks: manufacturing in a circular economy) are elucidated to classify the actions developed within the project boundaries to figure out the main impacts provided through different related projects to CF2. In addition, a short overview on the working groups (WG) of the DPM cluster is reported to show the scope within which the DMP cluster performs the operating activities.

- In chapter 2, the manufacturing industry trend and roadmaps are reported to guide the reader throughout the strategic plan proposed by Europe, focusing then on the SMEs and the supporting strategy developed for incentivising and stimulating them to go for a sustainable and digital path. The European Green Deal is elucidated to underline the commitment at international level and then, the Circular Economy roadmap developed by Regione Lombardia inItaly is shown to underline the commitment at national level.

- In chapter 3, the attention is moved to the concurrent need to integrate digital and sustainable solutions within the manufacturing domain. With this goal in mind indeed, it is spoken about the “Twin Transition” in Horizon Europe Program and the topics to be addressed.

- In chapter 4 the concept of Circular Economy is explained and further details are reported about the state of the art of Circular Economy adoption in the manufacturing sector form both a scientific and an industrial point of view. This chapter facilitates the reader in understanding what characterises this paradigm in terms of principles and possible strategies to be adopted to address the principles, and last highlights the main drivers and barriers emerged from recent studies.

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- In chapter 5 the Circular Economy concept is placed in the "Circular Economy pathway" promoted by the DMP cluster. Therefore, considering the emerged need by manufacturing companies to have a support to pursue the right path towards circularity, a tool aiming at assessing the circular maturity level of a manufacturing company has been developed. This tool is here described in detail in terms of structure and first validation.

- In chapter 6 the conclusions of the deliverable are reported to summarise the outcomes from the activities performed and to pave the way to future opportunities.

The link with the pathways and activities performed in CF1 and CF2 are described as follows. Connected Factories 1 (CF1) identified a number of key enablers and cross-cutting factors and developed five pathways based on them. These have been further refined in Connected Factories 2 (CF2) and needs for novel pathways have been recognised related to the data spaces and circular economy. At the CF2, WP1 will study the building blocks (presented at D1.2) that WP2 will use to develop the pathways. Those pathways will be broken down into five stages or levels of increasing maturity. The pathways will then be mapped across several key operations and milestones will be identified for each operation at each level Figure 1 .

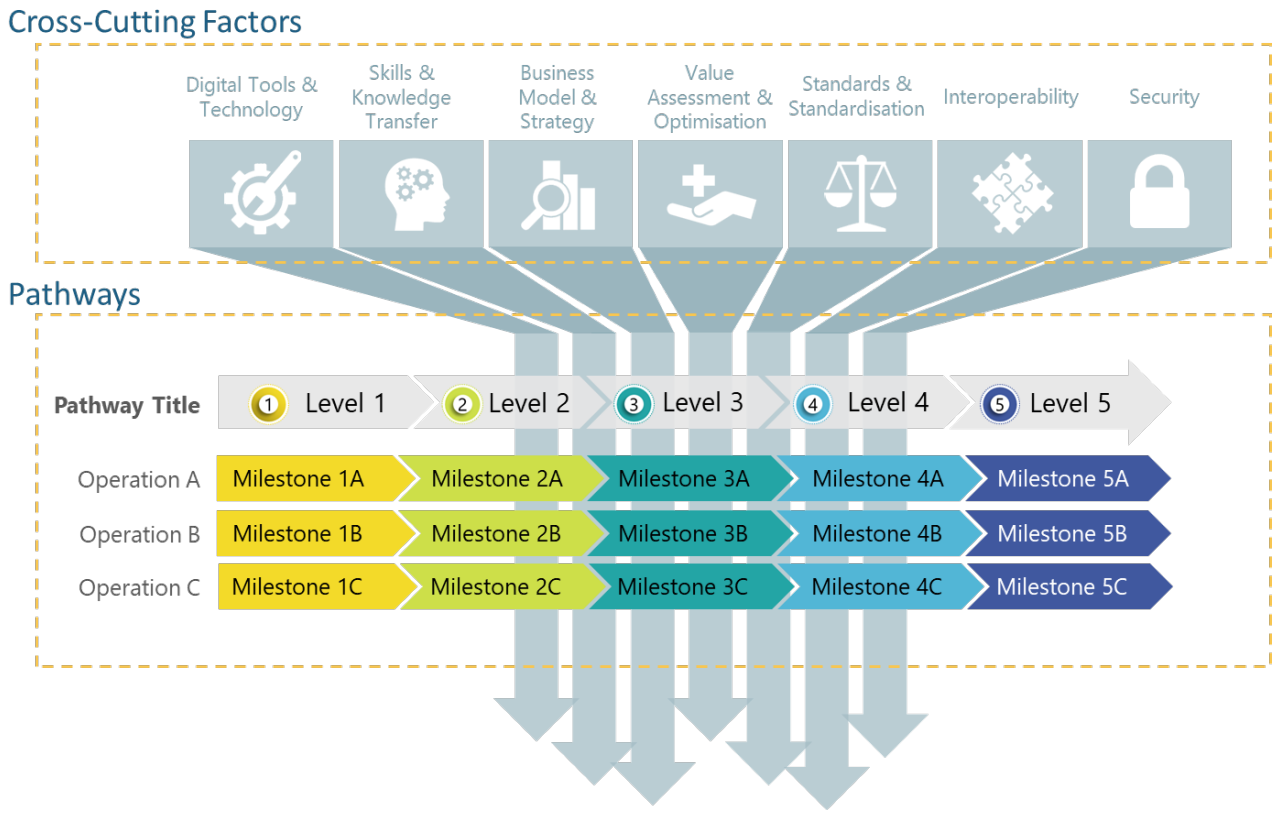

Figure 1 Connected Factories pathway development.

At the beginning of the project, we identified several questions: Will the cross-cutting factors (CCFs) hape the building blocks of the pathways or will they become the pathways themselves? Are the CCFs common to all pathways or specific to certain one(s)? Some of the CCFs have already been discussed in CF1, whereas some of them are new or modified at CF2. Similarly, there are pathways developed already at CF1 as well as

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novel pathways. This deliverable (D2.1.) focus on exploring and integrating the building blocks for the circular economy pathway developed and demonstrated at CF2.

1.1 The DT-ICT-07 four domains

The project is operationalised within the domain of "DT-ICT-07-2018-2019: Digital Manufacturing Platforms for Connected Smart Factories", an innovation action related to the Horizon2020 program. Therefore, considering that digital platforms are the essential elements for manufacturing companies to make possible the integration of new technologies, applications and services to face the continuous external change of supply and value networks, a special attention is required on them. Actually, the challenges to be addressed are to enhance the role of digital manufacturing platforms, to support the integration of different technologies, making data accessible to also enable complementary applications, to exploit new concepts and technologies.

More precisely, the development of the digital platforms for connected smart production facilities need to cope with four main target grand challenges:

1. Agile Value Networks: lot-size one (2018 call)
2. Excellence in manufacturing: zero-defect processes and products (2018 call)
3. The human factor: human competences in synergy with technological progress (2019 call)
4. Sustainable Value Networks: manufacturing in a circular economy (2019 call)

1.1.1 The DMP cluster and its Working Groups

The DMP cluster was born from the DT-ICT-2018-2019 topic. The 2018 call was focusing on the following two topics where three Innovation actions have been funded; the 2019 call was focusing on other two bullets where again three Innovation actions and one CSA (ConnectdFactories2 see below) have been retained for funding.

I. **Agile Value Networks: lot-size one** (2018 call)
   - **eFactory[7]. European Connected Factory Platform for Agile Manufacturing**. *The eFactory project realises a federated smart factory ecosystem by primarily interlinking 4 smart factory platforms, from the FoF-11-2016 cluster, through an open and interoperable Data Spine. The federation of the 4 base platforms is complemented by industrial platforms, collaboration tools and smart factory systems, specifically selected to support connected factories in lot-size-one manufacturing. The federated eFactory platform enhances value and reduces the barrier to innovation by providing seamless access to services and solutions that are currently dispersed. In parallel the platform provides the necessary infrastructure, tools and support for novel service creation and validations by third parties. Further, by fostering healthy competition in the smart factory ecosystem, the eFactory platform will ensure that the needs of the evolving smart manufacturing industry are met for the long term*.

II. **Excellence in manufacturing: zero-defect processes and products** (2018 call)

[7] https://www.efactory-project.eu/ now EFPF

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- **ZDMP[8]. Zero Defect Manufacturing Platform.** *Smart, SME Friendly, open, Zero-Defect Manufacturing Reference Platform, Apps, SDK, and Marketplace for Product and Process Quality in any factory for achieving excellence in European and Global Manufacturing. The ZDMP project combines state of the art technological approaches based on commercial grade standard or open-source or previous-project software with an innovative integration concept based on proven and integrating technologies. It provides Process and Product Quality support on top of a platform layer. These all can utilise ZDMP core services which can also be used to build ZD Apps which are placed on the ZD Marketplace. The ultimate aim is to establish a sustainable business and technological approach at the end of the project and launch "ZDMP Limited" assisted by the possibility of a crowdsourcing approach and ZDMP ambassadors.*
- ***QU4LITY Digital Reality in Zero Defect Manufacturing****. QU4LITY will demonstrate, in a realistic, certifiable and highly standardised, SME-friendly and shared data-driven ZDM product and service model for Factory 4.0. QU4LITY will also demonstrate how European industry can build unique and highly tailored ZDM strategies and competitive advantages (significantly increase operational efficiency, scrap reduction, prescriptive quality management, energy efficiency, defect propagation avoidance and improved smart product customer experience, and foster new digital business models; e.g. outcome-based and product servitisation) through an orchestrated open platforms ecosystem, ZDM atomized components and digital enablers (Industry 4.0 digital connectivity & edge computing package, plug & control autonomous manufacturing equipment, real-time data spaces for process monitoring & adaptation, simulation data spaces for digital process twin continuity, AI-powered analytic data spaces for cognitive digital control twin composable services, augmented worker interventions, European quality data marketplace) across all phases of product and process lifecycle (engineering, planning, operation and production).*

III. **The human factor: human competences in synergy with technological progress** (2019 call)

- **SHOP4CF[9] Smart Human Oriented Platform for Connected Factories**. *Europe's factories are getting smarter, and more sustainable. Finding the right balance between cost-effective automation and repetitive tasks and involving workers in areas such as adaptability, creativity and agility is the ultimate aim. In accordance with the highly connected factory model, a lot of data is being generated within the factory – by the embedded sensors and connected production equipment. All this information is useful in improving processes. The EU-funded SHOP4CF project will develop a platform on an open architecture that can support humans in production activities and provide basic implementation as a free, open-source solution. It will rely on pilots acting as the testing facilities and seeds for adoption of the platform.*

IV. **Sustainable Value Networks: manufacturing in a circular economy** (2019 call)

- **DigiPrime Digital Platform for Circular Economy in Cross-sectorial Sustainable Value Networks**. *Digital technology plays a big role in our transition to a circular economy, which aims to make optimum use of resources within industries. The EU-funded DigiPrime project will develop the*

[8] https://www.zdmp.eu/
[9] https://www.shop4cf.eu/

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concept of a circular economy digital platform in order to create circular business models based on the data-enhanced recovery and reuse of functions and materials. Specifically, it will create and operate a federated model of digital platforms for cross-sector business in the circular economy. DigiPrime will be validated through several cross-sectoral pilots, further detailed in 20 use cases covering different European industrial sectors (automotive, renewable energy, electronics, textile, construction), and by additional pilots in new sectors, funded through an open call mechanism.

- **KYKLOS 4.0[10] An Advanced Circular and Agile Manufacturing Ecosystem based on rapid reconfigurable manufacturing process and individualized consumer preferences**. *In circular manufacturing (CM), manufacturers find ways to eliminate waste by reusing and recycling materials and goods. The EU-funded KYKLOS 4.0 project aims to show how cyber-physical systems, product life-cycle management, life-cycle assessment, augmented reality, and artificial intelligence technologies and methods are able to transform CM. It will achieve this through seven large-scale pilot projects that will demonstrate improvements in operational efficiency and deliver solutions for resource reuse. It will further ensure the scalability of novel CM technologies, engage over 100 European industry actors, transfer know-how and mobilise additional sector investments. The project's advanced ecosystem can reshape factory processes and services so as to benefit manufacturing throughout Europe*.

The DMP cluster was born just at the beginning of 2019 under the initiative of the ZDMP project including eight main working groups. At the moment, all the 5 working groups have a stable composition with active contributions from all the 6 Innovation Actions and collaboration in place, some examples are given below in the description of the March 12th, May 13th, June 4th, September 25th and December 2nd-3rd DMP cluster meetings.

WG1. **Standardisation**. *Standardization clustering activities will connect standardization forums to facilitate the compliance of the cluster results with existing standards. Furthermore, the cluster will also contribute to new standardization activities where possible. At this point several standards were already identified and some terminology is apparently missing. This will lead to the development of a Glossary and an Ontology for Digital Manufacturing Platforms with a view to submitting into CEN as a CEN Workshop Agreement*.

WG2. **Dissemination**. *Events participation is an important activity to disseminate/discuss the clusters' advances. This topic considers the active participation in joint dissemination actions to communicate and promote the cluster results to technology and service providers as well as other business users and/or stakeholders. This activity foresees a) Joint event(s) participation, with joint booths, and b) Production of joint dissemination materials such as cluster brochure, poster, or video.* As an example see below the common DMP cluster template for presentations.

WG3. **Research and Socio-Economic Impact**. *Digital Manufacturing Platforms for Connected Smart Factories is a massive field of application, technology, and research on relevant innovation areas. Even within innovation projects, there is space to publish innovative results in leading journals and conferences. The second main objective is to establish a joint DMP Market Analysis and*

[10] https://kyklos40project.eu/

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portfolio of Business Models for DMP. This topic's strategy will be revised taking into consideration the confidentiality issues that are involved. Next actions should be agreed to share non confidential information about business models approaches for the three cluster projects as already individual projects work has progressed.

WG4. **Experiments (Pilots and Open Calls).** *Pilot activities will be jointly addressed by the three + three projects to increase knowledge on pilots' description, conducting, and assessment. Analysis of existing pilots' templates and descriptions will be used to achieve a possible common representation methodology and semantic interoperability. The collection of strategies to raise SME engagement and common strategies on privacy GDPR issues will also be addressed. Also this aspect will be properly addressed in the CF2 CSA (EFFRA Innovation Portal) and in the OPEN DEI Pilots Dashboard for cross-domain Pilots mapping and analysis. The open calls approach will enable external stakeholders (software developers, services providers…) to permanently improve components and develop new applications.*

WG5. **Platforms.** *Joint activities will exploit synergies between technology--based platforms addressing issues such as architecture, interoperability and standard approaches. This approach will enlarge the ecosystems surrounding the projects, facilitate the access for entrepreneurs / API developers/Makers and SMEs in general, and support the transfer of skills and know--how to industry. Activities will involve the analysis of existing reference architectures, specific requirements and needs. This will lead to the position of reference architectures, interoperability patterns and common cross-domain components, open source implementations mapped with reference architectures and Interoperability with existing projects marketplaces.*

Meetings have been held in those months and in particular, on December 2nd – 3rd meeting, the CF2 project has been organising the event.

Next DMP cluster meetings are scheduled for February 2021 (especially focusing in the WG1 Standardisation), also with a closer collaboration with cross-domain aspects.

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2 Manufacturing Industry trends and roadmaps

The manufacturing sector is experiencing a great period of change and innovation. The fourth industrial revolution has impacted in a positive way mainly on the productive activities of this sector and it is continuing to stimulate potential new improvements. Indeed, the fourth industrial revolution with its enabling technologies allows to revise both the internal operating and managerial activities and also the relationships established with other external industrial actors.

Although many positive changes are characterising this sector, other are required to be taken under control among which:

- *The increase of pollution generation*:
  Factories with their the productive and logistics activities generate huge among of pollution which negatively affects the society as a whole. The technological advancement can cope this problem.
- *The augment of primary material consumption*:
  Factories with their productive activities continue to require high levels of primary resources to satisfy the market demand and new sustainable solutions are searched to face this problem. Indeed, primary materials are treated as limitless while they should be managed appropriately to guarantee to satisfy the needs also of future generations.
- *The demographic changes*:
  People are moving to cities and this allows to have new workforce and new demand from the market. The average age of the humanity is increasing and new requests come from this change allowing the creation of new businesses.

2.1 A new Industrial Strategy for Europe

The European region has been always considered the place of Industry where new ideas for industrial innovation, and new business activities have been designed and shared worldwide. This allowed to position Europe as a pioneer for many industrial activities to be emulated by other foreign countries. There are different EU programmes, such as Horizon Europe, the Digital Europe Programme, the Single Market Programme, the Innovation Fund, InvestEU, the European Social Fund, the European Defence Fund and the EU Space Programme, and all European Structural and Investment funds which will help to promote the competitiveness of EU industry also in the future. The document entitled "a new industrial strategy for Europe" elucidates the current status and strategic plan https://ec.europa.eu/info/sites/info/files/communication-eu-industrial-strategy-march-2020_en.pdf

Considering the trends affecting the manufacturing sector, nowadays Europe is called once again to lead the change of the society by struggling to reach climate neutrality and by sustaining a digital transformation. Indeed, two main dominant elements are gaining momentum in the society: the twin ecological and digital transformation. This will affect everything, not only the society but also out economy and industry. This will require huge investments and new ideas of businesses that will shape the job profiles and needed skills maintaining the traditional values charactering Europe. In the twin transition it is required to open the focus on the industrial ecosystem taking into account all the players within the value chain.

Actually, the European industry is already undergoing a noteworthy change. First of all, it is experiencing a shift from products to services and from exclusive to shared ownership of products and services. Second, the extensive use of primary resources in productive activities is fostering the embracement of more circular and

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sustainable approaches to manufacturing. Thanks to disruptive technologies among which the 3D printing, Europe is trying to bring back many manufacturing activities.

As big floor behind these changes it is necessary to always keep in mind the sustainable pillars especially the environmental and the social one. For the first aspect, the industry needs to become greener also with the help of the digital transformation, making greener the products produced and the services deployed. Concerning the second aspect, the social pillar needs to be enhanced in the respect of the population, citizens and workforce social rights. In line with these goals, the new growth strategy of Europe is called "European Green Deal" and it aims at achieving the climate-neutrality by 2050. To do that, all the factories and their value chain need to be involved in this path and this requires "secure supply of clean and affordable energy and raw materials". Actually the objective is to create new markets for climate neutral and circular products and services. Clean technologies to reduce costs and improve market readiness are required also to implement novel industrial processes addressing sustainable requirements.

Therefore, as already mentioned, the digital transformation of factories would allow high level of efficiency and productivity of industrial activities, and it can be also the right gear boosting sustainability. Indeed, different clean technological solutions have been developed aiming at reducing for instance the carbon footprint. In addition, data management can be an essential element in this direction. The European Strategy for Data, set out by the European Commission, underlined therefore the need to create a framework allowing businesses to create, pool and use data to improve products and compete internationally strengthening the European traditional values in respect of the rights and privacy of all. Actually, European countries are investing in digital infrastructures, like the 5G network which can become a great driver for digital solutions.

Moreover, young tech-SMEs continuous creation might support more established industrial firms to adapt their business models and develop new forms of work for the digital age. Some opportunity has been already created, but these new forms of work need to be backed by modern and improved forms of protections. Moreover, it is required to set and ensure the right Intellectual Property policy helping to uphold and strengthen Europe's tech sovereignty. Indeed, IP would help in determining the European market value and its competitiveness. This is their intangibles, such as brands, designs, patents, data, know-how, and algorithms. Smart IP policies are essential to help all companies to grow, create jobs and to protect and develop what makes them unique and competitive. Another important issue refers to the "reinforced customs control" which allows to ensure that imported products comply with the EU rules and reduce the unfair competition.

Europe will support the transition as this picks up speed without leaving behind no one. It has been proposed the new Just Transition Mechanism that will mobilise €100 billion to ensure a fair transition for carbon intensive regions as they continue to transform their industries and economies. Companies must operate in reducing the emissions by first looking at the energy efficiency principles but then they need to have a secure supply of resources.

Factories need to revolutionise the way they design, and make things and support customers in modifying the way they use and get rid of things. This more circular approach will ensure a cleaner and more competitive industry by reducing environmental impacts, alleviating competition for scarce resources and reducing production costs. To support it, the new Circular Economy Action Plan paves the way for this direction. Indeed, it is proposed a sustainable product policy framework which defines the principles for all products to be defined circular and enhances the active roles of consumers to extend the product lifecycle.

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Moreover, the twin transition needs to be set upon an industrial innovation strategy based on disruptive investments which require patient and failure acceptance. In addition, to be competitive, the manufacturing sector requires to retain and recruit a qualified workforce which inevitable requires to update globally the education and to keep on pace the workforce training with a lifelong learning objective. Actually, the upskilling and reskilling are problems that are already affecting this transition. On one hand, there are already around 1 million vacancies in Europe of digital technology experts and, on the other hand, referred to the low carbon emission goal, it is expected to generate 1 million jobs by 2030. This will require an alignment among industry, Member States, social partners and other stakeholders through a new 'Pact for Skills' contributing to up- and reskilling and to unlock public and private investment in the workforce. In addition, a balance among women and men in industry is required to address the SGDs and thus, women need to be attracted, encouraged and incentivised worldwide in studying Science, Technology, Engineering and Mathematics.

All these actions require to be supported by investments throughout the financial system. The recent agreement on an EU taxonomy and the certainty provided by the Climate Law are big steps in the right direction to sustain sustainable investments. The Renewed Strategy for Sustainable Finance, based on that, will define clear rules to guide investors to sustainable investment. Moreover, the Commission's new Action Plan on the Capital Markets Union will include an initiative to strengthen intra-EU investment protection and efforts to unlock more diverse sources of funding for European businesses, especially SMEs continuing the work performed with the intension to deepen the Economic and Monetary Union.

Last, Europe needs also to reinforce its autonomy in this twin transition. Europe's digital transformation, security and future technological sovereignty depends on the strategic digital infrastructures (such as 5G, cybersecurity, Quantum Communication Infrastructure). Moreover, a more effective use of resources and technologies by creating also economies of scale can be achieved through the exploitation of synergies between civil, space and defence industries in EU programmes.

2.2 An SME Strategy for a sustainable and digital Europe

The above chapter allowed to provide the big picture concerning the European manufacturing sector current strategies and programmes. Actually, the manufacturing sector is based on a multitude of SMEs that thus the need to look at them starting from the documents " An SME strategy for a sustainable and digital Europe" https://ec.europa.eu/info/sites/info/files/communication-sme-strategy-march-2020_en.pdf.

If we look at the European scenario, we can see that there are around 25millions SMEs characterising the economy or our countries and they can all stimulate innovation in the great challenges and objectives already mentioned among which the climate neutrality and social cohesiveness allowing to address the European Industrial Strategy. This strategy requires to address all the needs coming from the different panel of European SMEs that are of various types in terms of business models, size, age, and entrepreneurs' profiles involving both women and men. In particular, three main pillars guide this strategy with the intention to lead a successful twin transition:

- Capacity-building and support for the transition to sustainability and digitalisation;
- Reducing regulatory burden and improving market access;
- Improving access to financing.

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The overarching goal is also to create an attractive place for new businesses devoted to a sustainable and digital innovation. This needs to be stimulated by the European Union and the member states. In addition, this strategy is built open already strong programs and foundations of the EU's existing SME policy framework such as the 2008 Small Business Act, the 2016 Start-up and Scale-up Initiative, the Competitiveness for Small and Medium Enterprises (COSME) Programme, and the SME support actions funded under the Horizon 2020 programme and the European Structural Investment Funds.

Concerning the sustainable transition, many companies, almost a quarter of the European SMEs, is already involved in this direction. Most of them already offer to the market sustainable products and services and they are based on flexible, high-tech innovative and well equipped systems. Part of them instead is experiencing administrative and legal challenges which limit their transition. Especially for this second group, the Enterprise Europe Network is offering tailored services to support SMEs in investing in more resource-efficient and circular processes and infrastructures and in finding the right partners to collaborate with. The European Institute of Innovation and Technology (EIT) will ensure that its Knowledge and Innovation Communities (KICs) is one of the supporters of SMEs development and through its support SMEs are expected to increase their opportunity to participate in local innovation ecosystems.

SMEs can be highly supported by digitalisation in improving the efficiency of production processes and the ability to innovate products and business models. Nevertheless, many SMEs are not able to grasp the value of data since they are not even aware about their value or they are not enough protected to participate in the agile economy. To cope with this problem, the Commission will devote efforts in improving data accessibility, allowing data flows between enterprises and governments based on common European data spaces. In guiding SMEs in the digital transition, the Digital Innovation Hubs cover prominent roles by also connecting the different structures.

SMEs have troubles in developing the right strategies for intellectual property and thus protect their R&D investments appropriately that is crucial for the twin transition. Among the actions, the Intellectual Property Action Plan will help in creating a more effective Intellectual Property systems effective for SMEs (e.g. by simplifying the registration procedure).

Another relevant challenge to be considered for the transition of SMEs regards their workforce and the limited availability of skilled employees due to the scarce financial resource usable for training activities or new employment. The skill gap is especially visible for digital skills. Activities for SMEs managers and employees in terms of upskilling are essential. These will be supported also by Member States that need also to pay attention and focus on the empowering of women to become founders themselves and thus, improve the gender balance. In addition, the Commission will update the Skills Agenda for Europe by including a Pact for Skills with a special element focused on the SMEs empowering based on vocational education and training (VET) that covers a relevant role for the SMEs workforce.

Actually, SMEs are often blocked due to regulations, standardisation and administrative formalities burdens. Indeed, due to the limited financial and human capital resources they face bigger problems than larger companies as reported in graph depicted in Figure 2.

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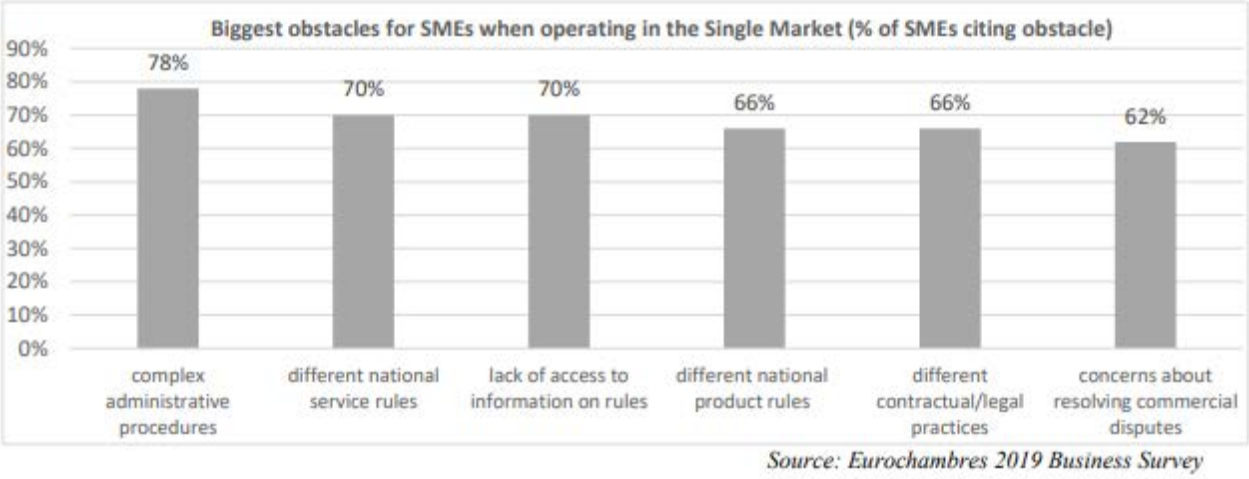

Figure 2 SMEs obstacles from Eurochambres 2019 Business Survey

Usually the big challenges are related to national legislations that should be managed by Member States and EU together to give the required support to SMEs. Indeed, thanks to the regulatory fitness and performance programme (REFIT), the Commission is able to systematically evaluate the existing EU legislation with the goal to reduce the legislation complexity and burdens.

The scaling up of these enterprises is limited in Europe and for this reason different actions have been put in place to improve their position and to make start-up develop their businesses. The Commission by cooperating with Member States and stakeholders will launch an initiative allowing to promote the adoption of best practices at national and regional level. This might allow Europe to become more attractive for Start Up and Scaling up. This initiative has the intension to make it easier to start-up and expand across borders, streamline the implementation of the rules on procedures for visa applications and residence permits for third country talent, make granting of employee stock options more attractive, promote venture-building and tech transfer from universities, increase access to finance for scaling-up, and promote cross-border digital tools. Moreover, the Services Directive cover a great position against market barriers. Indeed, the partnerships among border regions would support and enhance the cooperation between regional authorities that can help SMEs overcome market barriers in the provision of services.

SMEs are essential elements in the more and more dense networks of corporates, start-ups and SMEs alike working together across sectors and value chains to create the products and services of the future. For this reason, is necessary that SMEs and start-up would be supported in addressing their specific needs and would be involved in the EUs strategic values chains.

Also the Global Market is the right boost allowing the SMEs growth. Therefore, the Commission is promoting a SMEs friendly global environment by launching a new information portal to raise awareness of SMEs on trade policies and provide detailed information on customs procedures and formalities for exporting to third countries.

Financing remains still be overarching challenge for SMEs. For instance, in 2019 the 18% of SMEs in the EU did not obtain the full bank loan they had planned for. There is the need to diversify the sources of finance, even though it seems that the equity fundraising is increasing as well as the Venture capital one, these types of financing are eight times smaller in Europe than in US. Moreover, European investors, being not able to

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really evaluate the market potential and/or IP underpinning an SME's new tech service or product, they are not confident and sometimes reluctant in investing in here. Private investments are necessary for SMEs and thus, the Commission is promoting a program allowing to share the risk with the private sector. Another blocking issue is that in Europe there is limited possibility to be listed on capital markets through Initial Public Offering that contributes in limiting the financing growth. The introduction of an SME IPO Fund could be the opportunity for SMEs to be supported through and beyond the listing process.

Fintech innovation based on distributed-ledger technology ("blockchain") is an opportunity for SMEs to directly engage with investors, either via trustworthy intermediaries or decentralised by themselves. Moreover, it is necessary a diversity in terms of solutions and teams to boost innovation. Nevertheless, in 2019, more than 92% of venture capital raised by European tech companies went to all-male founding team.

To make SMEs growth and improve there is the need of support from EU and Member States since they both need to be committed and need to put in practice specific actions. The Commission is expected to publish annually an enhanced SME Performance Review. This review has also the role to monitor the national start-up friendly policies ("Europe Start up Nations" index), the engagement of SMEs in sustainable business practices, and last but not least the digitalisation of SMEs47 (DESI index).

2.3 A European Green Deal Strategy

As already widely mentioned before, the competitiveness of enterprise nowadays needs to take into account not only the economic sustainable pillar but also the social and environmental one. To support enterprise in this direction, the European Commission proposed the European Green Deal A European Green Deal | European Commission (europa.eu) which provides an action plan devoted to:

- Sustain the transition towards more clean and circular economy relying on the efficient use of resources
- Reduce at minimum pollution and restore the biodiversity

Therefore, the overarching goal is to reach climate neutrality by 2050 by stimulating the investments in the right directions. For instance, it will be necessary to invest in environmental-friendly technologies, to invest in decarbonising the energy-sector and to develop cleaner, cheaper and healthier forms of private and public transport. Moreover, it will be necessary to support the sustainable innovation of industries, to build energy efficiency buildings and enhance global environmental standards by collaborating with international partners.

The European Green Deal (European Green Deal) aims at guiding the European Union and its citizens towards climate neutrality. Indeed, without a strong commitment a difficult situation where the atmosphere is warming and the climate is changing annually, one million of the eight million species on the planet are at risk of being lost and forests and oceans are being polluted and destroyed, is a risk of becoming worse. Thus, with the Green Deal it is expected to support a drastic change and start a period of prosperity in a conscious and fair way towards nature. The goal is also to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts, thus to decouple the economic growth from the resource use.

Europe has to be cohesive in the sustainable path by involving all the citizens together with national, regional, local authorities, and industries. Actually the Green Deal represents the tool to address the United Nations'

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2030 agenda and create awareness about the importance of a sustainable development and the sustainable development goals. Figure 3 represents the element characterising the European Green Deal.

Figure 3 European Green Deal elements from the "European Green Deal" official documents

To allow that this transition would happen in an inclusive manner, new policies are required and these need to be ad hoc designed. Thus, while new values must be given to the protection and the restoration of natural systems, on the other side there is also the necessity to stimulate the digital innovation and transformation since these tools are fundamentals to undertake the sustainable change of the society.

Some successful actions have been already put in place. In March 2020 it was proposed the first "Climate Law" that allows to insert in the legislation concrete actions to achieve the climate neutrality by 2050. Some achievements in the last decades have been accomplished such as a reduction between 1990 and 2018 of the 23% of the greenhouse gas emissions with a growth in the economy of 61%. The current goal is to reduce by 50% the greenhouse gas emissions by 2050.

The new legislation aims also to ensure the right carbon pricing throughout the economy by supporting a change in the behaviours of consumers and enterprises. In line with that also the taxation will be updated and aligned with the goals for the 2050.The problem that might be faced by Europe is the not-alignment of the other countries with these goals which indirectly could create a carbon leakage since part of the production might be transferred to other countries or some intensive-carbon products are imported. To cope with this risk, the Commission aims to propose a carbon border adjustment mechanism for specific sectors. In particular, in this way the price for imports will reflect the carbon content.

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To achieve the climate neutrality objectives and reduce the greenhouse gas emissions, as just stated, it is necessary also to introduce the decarbonisation of the energy system. It is necessary to involve consumers in this transition and it is necessary to create cross-sectors solutions otherwise it would not be successful. Actually, smart infrastructures need to be created and the energy poverty needs to be addressed to ensure to give everyone basic standard of living. Steel, chemical and cement sector are energy-intensive sectors but represent indispensable value sources for the European economy. For this reason, their decarbonisation and innovation is essential.

Another important issue regards the still widely present linear economy. Indeed, only the 12% of resources comes from recycling while the others are extracted and this inevitably increases the greenhouse emissions levels. Actually the shift from linear to circular economy could be an opportunity to create new jobs and profiles. This is especially true if we look at the expected twin transition which won't be based only on green profiles but also technological one.

Products need to be designed differently to respect the expected results by 2050. For this reason, it has been launched the Circular Economy action plan in which sustainable product policy is defined and guidelines on how to design circular products are reported to enable the multitude reuse of the same product or its resources through subsequent lifecycles. Moreover, this action plan aims to involve consumers by stimulating a change in their behaviours. Indeed, enterprise will be encouraged in offering circular products and consumers will be allowed to choose reusable, durable and repairable products in a more conscious way.

In this direction, the information management and sharing cannot be neglected. Therefore, information needs to be reliable, comparable and verifiable to enable buyers to make more sustainable decisions limiting the so called "green-washing" effects. Indeed, companies will be required to assess their products based on a standard procedure to make "green claims" in order to ensure their reliability and avoid false claims.

Besides the greenhouse gas emissions reduction also the waste generation needs to be managed appropriately. Therefore, the value retained in waste needs to be recovered to be fully exploited, and the waste impacts on climate change needs to be eliminated or at least minimised. To cope with this issue, ad hoc legislation requires to be developed and new measures needs to be adopted. Indeed, the Commission has to consider legal requirements aiming at boosting the market of secondary raw materials with mandatory content.

Another important element for Europe is to ensure the supply of resources and of the sustainable raw materials. To be more precise, it is necessary to set the correct strategy by diversifying the primary and secondary sources, to ensure to have the critical raw materials necessary for clean technologies, digital, space and defence applications. In addition, it is necessary to develop breakthrough technologies in key industrial sectors by 2030 to address the main goal (e.g. clean steel breakthrough technology leading to zero-carbon steel making process).

New forms of collaboration are essential to commit enterprises in this transition. New sustainable value chains need to be created and empowered (such as the Strategic Action Plan for the Batteries to create a European Battery Alliance).

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As just mentioned digital technologies will represent fundamental elements in these direction. Indeed, digital technologies such as artificial intelligence, 5G, cloud and edge computing and the internet of things might boost and maximise the impact of policies designed addressing climate change and protect the environment.

Energy efficiency needs to be sustained also through the construction sector. Indeed, building account for 40% of energy consumption. It is necessary to increase the renovation rate of building stock and in parallel it is necessary to keep houses enough warm addressing also economic sustainability. This requires on one side to empower the renovation rate of public and private buildings through the concurrent engagement from Member States and EU, and on the other side it requires to strengthen the legislation on the buildings energy performances by assessing the emissions from buildings and by boosting the design of new buildings addressing the circular economy principles. This second issue could also support the economic sustainability of building management and support those householders struggling to pay their bills at the end of the month and also improve the public sector building sustainability (e.g. hospitals and schools).

Besides buildings, the transportation sector is quite polluting, and it is necessary to reduce the greenhouse gas emissions for the 90% to achieve the carbon neutrality. The Commission has boosted the smart mobility and these actions will be kept updated. Others have been planned or already put in practice, among all the multimodal transport received a boost and the 75% of inland freight carried by road will be shifted to water, introduction of automated and connected multimodal mobility will be highly supported together with the smart traffic management. Moreover, it has been thought that the price for transport must be aligned with its emission and its overall impact on the environment. Looking at the public transportation in cities, actions to make it less polluting is required.

Another driver of the European competitiveness regards the food industry. Indeed, European food is well known all over the world as a safe, with good nutrients and of high quality. These characteristics must become the global standard for sustainability while keeping in mind the fast-growing population worldwide. Until now there are still some issues on food production since it still generates negative impacts on the air, water and soil pollution, it contributes to the reduction of biodiversity and climate change, and it is still affected by an excessive use of natural resources considering also that food waste is still a big problem in our society. A reduction on chemical pesticides, fertilisers and antibiotics usage is required and new legislations will be proposed. Actually, this scenario can benefit from the new sustainable demand from the market and the advancements in technologies. Supports to fishermen and farmers will be given directly from the EU since they cover a detrimental role for the transition, but adequate policies and regulation are required to keep on the working activities in a sustainable way. Above all, the “Farm to Fork” strategy can empower the efforts to achieve climate neutrality since common policies represent the key tools for a successful and sustainable transition and since it can contribute to really embrace the circular economy principles. Indeed, it can stimulate the aware and conscious sustainable food consumption and promote affordable food for everyone since non-compliant imported food would not be allowed on the European market. Moreover, actions to allow to provide consumers with reliable and relevant information will be put in place.

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Specific countermeasures and actions will be put in place to address the biodiversity reduction problem. The Commission together with the Member States will set specific actions to be adopted to restore the ruined ecosystems and cross-border collaborations will be required. Concerning the ocean and sea side, a sustainable blue economy needs to be defined and the actions will be driven by the analysis of the special report on oceans named "International Panel on Climate Change".

The aim is also to create a toxic-free environment and to cope with this, the Commission is expected to adopt in 2021 a zero pollution action plan for air, water and soil and Member States will be asked to align their actions to the policies generated. For instance, the World Health Organization requirements will be the input to define the air policies. In addition, hazardous chemicals will be substituted by more sustainable and innovative alternatives.

Many investments in different areas need to be performed affecting and involving both the private and the public sectors. The Commission has to design an appropriate Sustainable Europe Investment Plan to support and guide appropriately the investments. A Transition Mechanism will be also activated to support those sectors whose production depend on fossil fuels or carbon-intensive processes. A taxonomy for classifying environmental sustainable activities has been developed. This will ensure a guidance for sustainable investments and thus, it will be easier for investors to identify credible sustainable initiatives. Moreover, it will ensure to integrate in the financial system the climate and environmental risks.

Green budgeting tools must be inserted to direct towards green priorities the public investment, consumption and taxation. In line with that it will be inserted a tax reform to boost the economic growth and create the right resilience against the climate change.

Also direct researches in this direction is necessary to achieve sustainable goals. Indeed, innovation and new technological solutions are core elements for the transition. It is necessary to keep the competitive advantage in clean technologies. Before the research, also the basic training will be adjusted at companies' level too and a re-skilling and upskilling will be supported. Last, investments to make school buildings more sustainable will be done.

To conclude, the updated legislations will be updated according to the suggestions received from the stakeholders which will be allowed to provide their feedback on open platforms. Collaborations with external continents such as Asia and Africa can allow to achieve high quality results at global level.

2.4 A digital roadmap for a circular economy

Circular Economy paradigm is one of the main elements of the European Green Deal since it can represent a great solution towards climate neutrality and efficient use of resources. Actually, its adoption can be highly facilitated by the introduction of different digital technologies as reported in the document developed by the European Policy Centre named "A digital roadmap for a circular economy"(A digital roadmap for a circular economy). According to the document indeed, the concurrent innovation based on both circular economy and digitalisation allows to create a digital circular economy which can really contribute to the achievement of the objectives on the European Green Deal keeping high levels of competitiveness in Europe as depicted in Figure 4.

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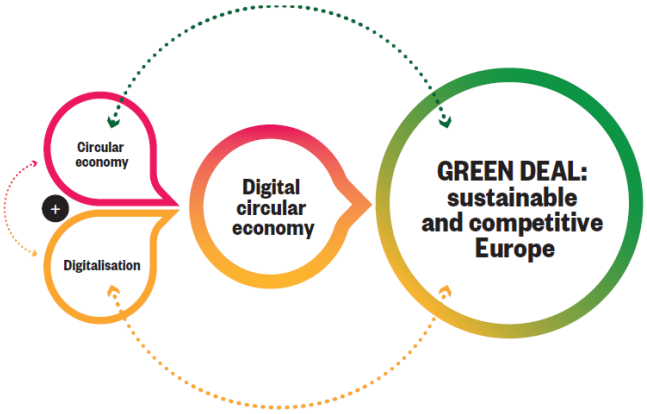

Figure 4 Circular Economy + Digitalisation from "A digital roadmap for circular economy"

Indeed, the combined innovation on both sides allows to be more successful on the transition. The European Commission has to guide the actions on the two sides in an aligned way to ensure that the efforts would be paid back by the achievement of the climate-neutrality goal by 2050 and by the possibility to keep on the long-term high level of sustainability. In particular, the exploitation of the data economy and allows the development, deployment and scale-up of the sustainable, digitally-enabled solutions identified to boost a more sustainable circular economy.

Actually, digitalisation represents the way in which it is possible to achieve the European goal and adopt Circular Economy by using resources through different lifecycles by maximising their values. The data and digitally solutions to be adopted to empower business activities embracing circular economy principles can be based on digital platforms, smart devices, Artificial Intelligence, 3D-printing, digital twins, IoT and blockchain. Therefore, all these solutions can be the great options required when it is necessary to enhance transparency, connectivity and information sharing. Circular Economy needs to be embraced by consumers as well to be effective and to have long term impacts. For this reason, it is necessary to create the right awareness in them to make conscious choices on products and on their usage, and this can be done via digitalisation (e.g. by introducing smart products on the market). Digital technologies can also boost the adoption of Circular Economy considering different issues among which the design, production, consumption, reuse, repair, remanufacturing, waste management and recycling as reported in Figure 5.

Figure 5 Digital Circular Economy from "A digital roadmap for circular economy"

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Actually to allow that the twin transition would take place in a structured way, a guidance from policymakers needs to be provided Figure 6. This means that the contributions developed on the digital side needs to be directed in a manner that would allow the achievement of the sustainable goals and to avoid the rebound effect. Therefore, four key elements must be respected to obtain the expected goals:

- *Define a vision and act accordingly* to make Europe become leader is utilising data and digitally-enable solutions and to extend the product lifecycle by being supported by the synergies among the digital and sustainable solutions,
- *Use governance, policies and regulations to provide a framework for action* by allowing the data and information sharing and access, providing digitally-enabled services, improving the e-commerce and the eco-design.
- *Use economic instruments to encourage and enable the transition* by introducing the right financial tools, by supporting the reskilling and upskilling of the workforce and by directing the investment.
- *Strengthen partnerships and empower citizens* by relying on the usage of the already existing stakeholders' platforms, by underlying the benefits for data exchange increasing the trust in their relationships.

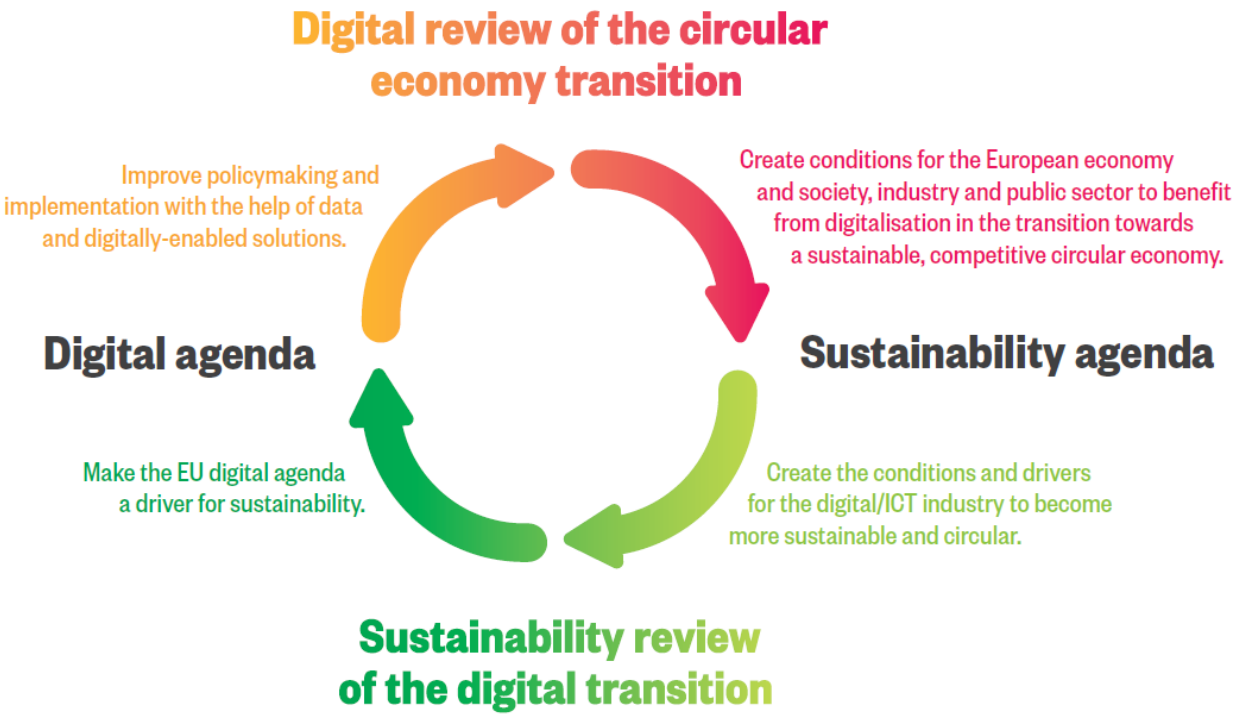

Figure 6 Digital and Sustainable Agenda

2.5 The Circular Economy Roadmap of Lombardy Region (Italy)

In this context, where the concept of Circular Economy is more and more gaining momentum, also national initiatives have been developed. Among all, in Italy, and more precisely in Lombardy, a roadmap guiding the research and innovation concerning Circular Economy paradigm has been designed (Lombardy Roadmap for Research and Innovation on Circular Economy (regione.lombardia.it)). Actually, this roadmap aims to allow the entire region to undertake a structured path towards circularity within the Smart Specialization Strategy

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of the Lombardy Region 2021-2027. This roadmap should stimulate the collaboration and cooperation between the private and public sectors to support the emerging initiatives with financing instruments. In addition, it could allow to anticipate market needs by address the merging social needs, and driving the sustainable transition trying to satisfy the climate and environmental world challenges settled by ONU Agenda 2030. This kind of regional roadmaps are important tools to implement European level strategies as they turn the strategic agendas to actions and bring them closer to different stakeholders. For instance at Finland the world's first national road map to a circular economy was published in autumn 2016. The road map's second edition updates plans to reform its economic model to ensure successful sustainability. It reflects the actions needed from the perspectives of different stakeholder groups; citizen, enterprise, municipality and central government[11] Here, the roadmap of Lombardy region is presented as an example of regional CE roadmap.

The implementation of a roadmap would empower the reinforcement of inter-regional cooperation that could indirectly impact on the creation of new European value chains. Moreover, the roadmap has been designed in a peculiar historic period caused by the COVID-19 pandemic which has highly affected both the Italian economy and the worldwide economy creating the awareness about the need in the future to be faster and reliable against the external changes. Actually, the roadmap has been developed once analysed the current status of Europe in respect to Circular Economy adoption for than focus the attention on the Italian context. Indeed, the roadmap elucidates and defines the possible approaches to be adopted in undertaking the transition.

Actually, the roadmap, based on the already diffused and consolidated roadmap developed by AFIL (Associazione Fabbrica Intelligente Lombardia) https://www.fabbricaintelligente.it/roadmap-fabbrica-intelligente-industria-4-0/ , describes the Research and Innovations priorities along the product values chain in a Circular Economy context as reported in Figure 7 .

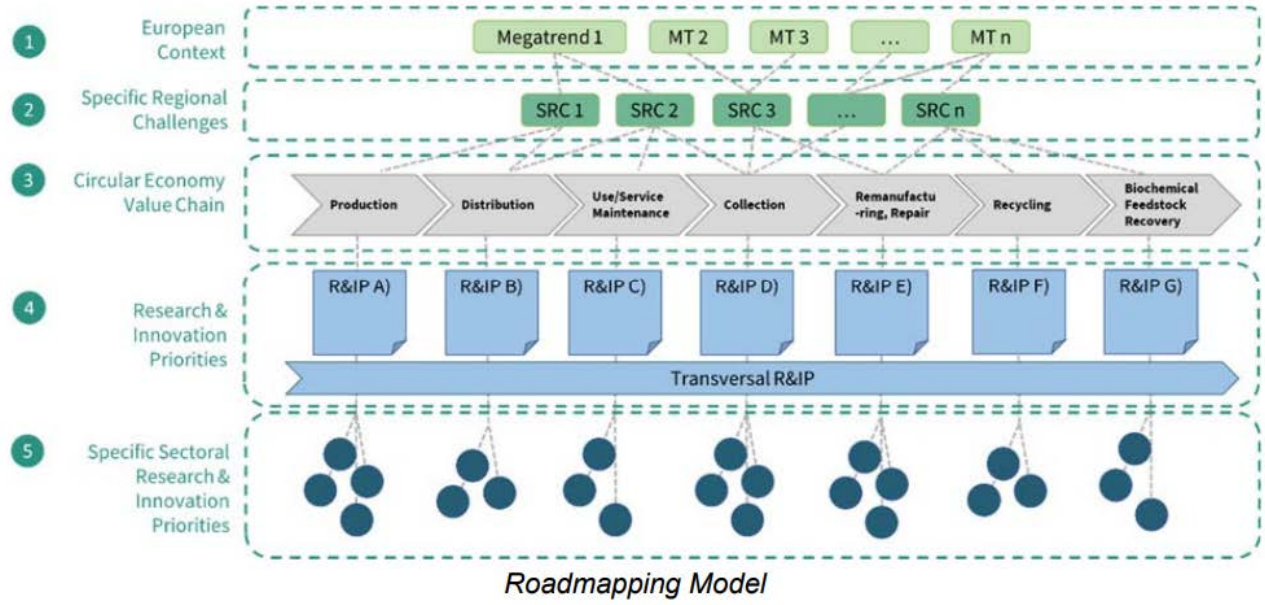

Figure 7 Circular Economy Roadmap from Regione Lombardia

[11] https://www.sitra.fi/en/projects/critical-move-finnish-road-map-circular-economy-2-0/#your-role

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More precisely, the European context has been investigated in detail to match it with the specific regional needs allowing, through a mixed approach bottom up and top down, to ensure the identification of the most relevant priorities to be addressed. This is performed according to the context and by looking at the specific phases of a circular value chain which has been considered to start from the "production" phase and to end with the possibility to recycle the materials through the "recycling" processes. This value chain is better described in Figure 8 and it has been taken from "*Synoptic report Opportunities, Barriers and Value Chain analyses*" according to which the value chain starts from resource gathering and ends with waste valorisation.

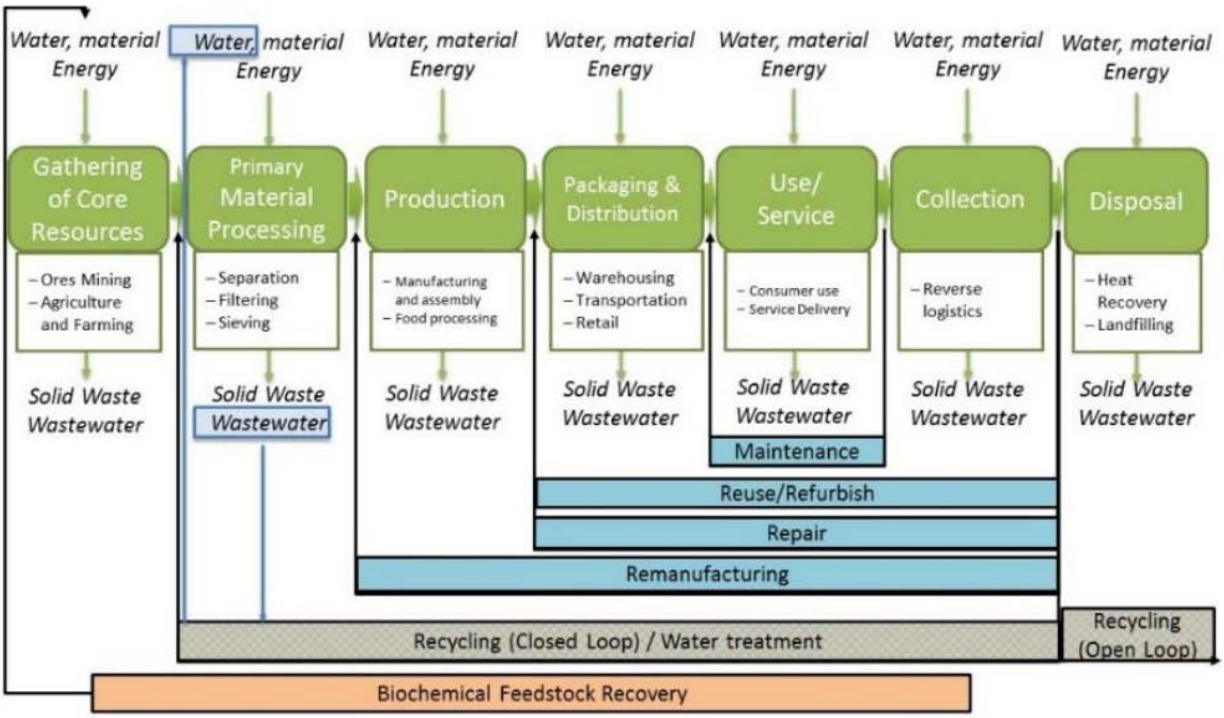

Figure 8 Circular Value Chain Model from "Synoptic report Opportunities, Barriers and Value Chain analyses"

The roadmap developed by *Regione Lombadia* on this value chain model represents the guiding instrument allowing to understand the requests for innovation which are inevitable to undertake such a big structural change required by the transition. Moreover, the Italian context is based on a multitude of creative and flexible SMEs which can foster their competitiveness in the European scenario and their position in global value chains if adequately supported. In particular, Lombardy since 2015 has committed itself to struggle to fight climate change and this roadmap would help the region and the entire nation to achieve this goal.

Below are summarised the main research priorities detected according to each single value chain phase.

- **Production**

  Design for Circular Manufacturing: there is the need to research on how modify the product design in accordance to the circular economy principles aiming at extending the resources lifecycle. In addition, it is necessary to inset secondary raw materials in new products. To achieve these goals, it is necessary to create collaboration between manufacturers, consumers and recyclers

  Circular Production Processes: it is necessary to cope with the waste generation during production activities, that is possible if adequate technologies are adopted among which the

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advanced data-enhanced solutions. Indeed, cyber-physical systems for quality-oriented feedforward process control can monitor the propagation of defective products and thus scraps. Moreover, the production activities make generate by-products which need be treated to give new values to them by relying on industrial symbiosis mechanisms. Last, all the processes must be designed to be flexible and reliable against changes.

Enabling traceability in product and processes: in order to have the information about the characteristics and conditions of products to allow their lifecycle extension. Actually, it is necessary to first understand what are the relevant data to be acquired and stored along the product lifecycle and there is still work on-going on this topic. Moreover, data might come from different stakeholders which are required to collaborate and share their private data, for instance on shared digital platforms. Also traceability needs to be boosted relying on standard protocols and last, the creation of certification of re-usable products, components and materials needs to be considered.

Cross-sectorial business models for circular economy: to systematically expand businesses into cross-sectorial realities to unlock the potentials of circular economy

Support to Circular Economy Oriented Production: institutions need to actively support Circular Economy-oriented industrial initiatives offering economic and operational support

- **Distribution**

  Establishment of Synergies Among Forward and Reverse Logistics: to create a unique or coordinated structure to deliver and collect products

  Development of Market/Pricing Strategies to Increase the Willingness to Buy of Sustainable Products: this would allow to reduce the costs of products with embedded secondary raw materials and increase the quality perceived on these products

  Exploitation of Local Production-Distribution-Consumption Networks: by decentralizing in different areas the production and distribution centres to enhance the competitiveness of the different areas in the world.

  Circular Economy Driven Public/Private Procurement: to provide the right incentives to companies in becoming circular.

- **Use/Service Maintenance**:

  Product life-cycle extension: to avoid to substitute still functioning of repairable products and components. This can be done thanks to traceability and data sharing.

  Product service systems: based on the selling of the service and the non-ownerships of products to have a greater monitor over them.

- **Collection**:

  Reverse logistics: needs to be introduced to ensure the extension of the product lifecycle. It could be based on “take-back” protocols for re-use to create value from re-used products by systematically implementing the most profitable circular economy strategy. Also waste management protocol must be defined to unlock the potential residual value of resources and safety hazardous products transportation protocols need to be developed to allow the minimum problem generation

  Citizens engagement and incentives: to enforce their collaboration and use of take-back programs.

- **Remanufacturing, Repair**:

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Innovative Remanufacturing Technologies: technical solutions must be put in place by companies to allow the remanufacturing and repair of products. This can be done to update or restore components and product functions. This requires the introduction of innovative technologies among which Artificial Intelligence for the product characterisation of the product residual state, or decision support systems for disassembling, simulation etc.

Distributed and Flexible Remanufacturing Networks: to allow to enhance the skills and distribute the work in a structured way within networks

- **Recycling**:

  Innovative technologies for sorting and recycling to allow to be more efficient in these processes and avoid to obtain the opposite outcome. In addition, flexible and reconfigurable recycling systems need to be inserted to allow to face the different change in demand. Introduced robotics as supporting tools.
- **Biochemical Feedstock Recovery**:

  Develop new biotechnologies: to reduce the dependency to natural resources and create value from what is now considered worthless.

  Valorise bio-waste to support the transition from fossil-based to bio-based processes

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3 Towards a European Twin Transition in Horizon Europe Program

In the previous chapters, both the national and international current situations have been described and it has been elucidated many times the importance to go for a so called "Twin Transition" to allow the achievement of the European goals. In line with that also the Horizon Europe Program supports researches in the domain of the twin transition. Below is reported some extraction from the program.

In particular, Destination 1 of the program is focused on the "Climate Neutral, Circular, and Digitised Production" and it aims to undertake the following three key strategic orientations:

- Make Europe become the global leader to exploit digital potentials to address circular, climate-neutral and sustainable economy by modifying different sectors among which the mobility, energy, construction and production systems

- Make Europe promote the open strategic autonomy based on the leadership of the development of digital enabling and emerging human-centred technologies, sectors and value chains to boost the twin transition

- Make Europe the leader in creating a resilient, inclusive and democratic society.

Actually, accelerating the twin transition allows to strengthen the position of Europe globally and to confirm its competitiveness based on a long lasting prosperous growth. This transformation necessitates new technologies, investments and researches in innovative solutions to make happen the concurrent exploitation of the two sides of the change.

Some of the sectors will be majorly affected while others less, and thus tailored supports need to be provided. Actually, the collaboration and commitment of all the sectors, among which the discrete manufacturing, the construction and energy intensive industries and the process industry, is the right element required to achieve the European Union's climate-neutrality goal. Indeed, the European manufacturing sector gross added value accounted for 2.076 billion in 2019 and it employs 30million people. The process industry is also a great gear for Europe, but it must face two challenges: the pressure form Asian countries and the environmental impacts.

With these goal in mind, the first Work Programmes the outcomes from Research and Innovation must address the following aspects:

- Boost twin transition of manufacturing and construction sectors
- Develop new green, flexible and digital solutions to design and produce goods
- Attract new workforce for the construction and manufacturing sectors
- Define concrete and applicable pathways to contribute to address the climate-neutrality goal
- Empower Europe making it increasing in terms of productivity, innovation, capacity, resilience, sustainability and global competitiveness
- Find solutions to reduce waste generation and CO2 emissions

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In order to address these overarching goals, different topics have been detected to be structured in different proposals. Those below reported, coherent with the manufacturing sector, are than further analysed in the next sub-sections:

1. Green, flexible and advanced manufacturing
2. Advanced digital technologies for manufacturing
3. Hubs for circularity, a stepping stone towards climate neutrality and circularity in industry
4. Enabling circularity of resources in the process industries, including waste, water and CO_2/CO

3.1 Green, flexible and advanced manufacturing

Under the group named "Green, flexible and advanced manufacturing" different proposals are invited and these are below described.

- First of all, there is the Innovation Action "**HORIZON-CL4-2021-TWIN-TRANSITION-01-02: Zero-defect manufacturing towards zero-waste (IA)"** according to which the expectation is to propose projects aiming at developing solutions focused on the production line or system with the goal to reduce the defects generated by improving the overall quality in a holistic manner to achieve the "first-time-right" goal. The projects developed in this area should target specific waste or discarded materials and components which are usually considered difficult to be reworked or recycled. This requires to provide solutions also at systems level focusing on for instance the integration of control systems, and on the integration of non-destructive inspection methods. Moreover, the use of large scale data is suggested.

- Under the same topic there is also a research and innovation action named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-03: Laser-based technologies for green manufacturing (RIA)".** This proposal needs to support the innovation on laser-based technologies such as milling, turning, grinding, laser processing, surface treatment, forming, and additive manufacturing in order to integrate the high-power lasers and tailored beams with quality sensors and real time monitoring systems. This should allow innovation concerning the manufacturing and re-manufacturing tools. This innovation allows European industry to become a leader in agile and green manufacturing based on laser-based technologies. In addition, it stimulates the versatility of processes making them simpler to reconfigure and manage relying on data exchange.

- The last call concerning this topic in named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-05: Manufacturing technologies for bio-based materials (RIA)".** This proposal needs to stimulate the innovation towards circular systems. Indeed, new materials and techniques to produce materials need to be detected and analysed in order to ensure to embrace this economy. This field combines several research areas among which the one of chemistry, engineering, physics, biology and material science with the goal to produce bio-based products. Indeed, bio-based products would allow an easier management and extension of the product lifecycle keeping its reuse and recycling a sustainable option easily adoptable. These materials are good substitute for artificial materials driving towards a truly sustainable manufacturing industry. These materials can be introduced to

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address the need to lower the environmental impact with high technical properties. To boost their introduction new technologies can be adopted such as the additive manufacturing allowing to unlock the potential of bio-based materials. In addition, the upskilling and workforce is required to address the new needs.

3.2 Advanced digital technologies for manufacturing

Concerning the second area, "Advanced digital technologies for manufacturing" two proposals are present tackling this topic from different perspectives.

- The first one is named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-07: Artificial Intelligence for sustainable, agile manufacturing (IA)**" and it aims to transform the entire manufacturing and process industry with the introduction of Artificial Intelligence (AI) addressing the whole product lifecycle. In particular, the intension is to provide AI-based solutions to companies to improve the sustainability of their processes without the need of highly skilled workforce. The personnel will be supported in creating more flexible and resilient processes against the external and internal needs of change. Indeed, the introduction of AI would allow to optimise processes actions with minimum inputs from the operators. These researches would allow to position Europe as leader in AI solutions and would strengthen the efforts in standardisation of AI in manufacturing, they would improve the sustainability of the industrial processes from the three spheres of social, economic and environmental sustainability, they would empower humans in performing industrial activities, they would increase the European industrial resilience.

- The second proposal is named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-08: Data-driven Distributed Industrial Environments (IA)"** and it aims to rely on the potentials of data to improve industrial processes. Therefore, it is necessary to understand the right balance between storing and handling data centrally in cloud or locally. Issues like efficiency, real time needs and cybersecurity must be addressed and deeply investigated in order to provide the right solution according to the requests. In this context also technologies like, computing storage and networking technologies must be studied in order to guarantee the expected flexibility along the entire value chain. In addition, this could support the creation of new business models based on the available industrial data coming from different sources and ontologies guided by trust. Indeed, new specifications and standards for data will be defined to enhance the collaboration and cooperation among different actors. These innovations can be backed by those regarding the 5G that can improve resilience and cybersecurity by design. Private 5G networks have been already adopted by some industrial actors since they have the potentials to be tailored on manufacturer needs and adapt themselves according to the future requirements, but simplified approaches are needed for their extensive usage. These researches would empower the position of Europe as leader is exploiting data-driven manufacturing solutions which would empower its agility against changes and they would foster data and distributed computing standardisation.

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3.3 Hubs for circularity, a stepping stone towards climate neutrality and circularity in industry

Another group of proposals aiming at stimulating the sustainability of the manufacturing sector is the one named "**Hubs for circularity, a stepping stone towards climate neutrality and circularity in industry"** whose intension is to stimulate the collaboration among industrial actors to reach the climate-neutrality goal.

- The first proposal is named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-14: Deploying industrial-urban symbiosis demonstrators for the utilisation of energy, water, industrial waste and by-products at regional scale (RIA)".** This research and innovation action aims to address the requests coming from the Circular Economy Action Plan according to which the development of industrial symbiosis network especially in urban areas must been powered and exploited. Through this solution, waste can become the feedstock for other industrial processes. This would support the usage of urban waste and develop the so-called urban mining. This research is going to cover several social aspects, among which the community improvement. It is necessary through this research to involve the local communities and create awareness in them. Some assessment tools based on sustainable KPI is requested to be developed to monitor the industrial symbiosis performances. In addition, new internal solutions to adapt product and processes with the external needs will be introduced.

- Another proposal in named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-15: Circularity flows for solid waste in urban environment (IA)"** and it fosters as well the systematically establishment of circulation of solid waste in urban area. Indeed, solid waste represents for Europe the 30% of the total amount of the waste generated and if solutions for reuse or recycle this waste would be found, this would positively impact on the reduction of emissions due to mining. Innovative solutions must be developed among which the designing of new ways of waste management to valorise waste at maximum. Internal processes must be updated to include secondary material coming from waste in the traditional activities and this requires also to ensure the quantity and quality of these materials. In addition, the community as well must be involved to reduce he possible barriers.

- A third call named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-16: Hub for Circularity Community of Practice (ECoP) platform (CSA)**" aims to create a European Community of Practice allowing to concretely connect hubs for circularity (H4C) and the actors interested in investing in industrial urban symbiosis to create new circular value chains. Indeed, these hubs could represent the mean through which achieve the climate-neutrality goal sustained by Europe relying on predefined specification and criteria different according to the context. This requires to analyse the existing collaboration models, tools and technologies, to create a roadmap to achieve the effective implementation of these hubs by fostering also the relationships among businesses and territories. These relationships can be fostered by organizing tutorials and learning framework adoptable by the community members which would allow the knowledge transfer.

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3.4 Enabling circularity of resources in the process industries, including waste, water and CO2/CO

The last topic highlighted by the Horizon Europe Program regarding industrial sustainability is the one called "**Enabling circularity of resources in the process industries, including waste, water and CO2/CO**" which makes focuses the attention on the process industry looking at waste generation and CO2/CO emissions during industrial activities.

- The first proposal to address this topic is named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-17: Plastic waste as a circular carbon feedstock for industry (IA)**". This innovation action allows to focus the attention of plastic waste with the goal to understand how to use it as carbon feedstock for the industry thus, by reducing the demand for plastic on the long run which indirectly lower the emissions generated having a beneficial impact on the environment. Therefore, this researches is devoted to valorise all the unsorted plastic waste avoiding their landfill, to allow the 100% utilisation of the electrified processes and reduce for the 60% the GHG emission generation along the entire lifecycle in comparison to the traditional recycling processes. Indeed, the usage of plastic waste could represent a great alternative for Europe in respect to the imported feedstock such as oil and gas. To do that, innovative technologies must be developed and the processes addressed must be those which treat the material of high interest for industrial companies. To prove the beneficial impact, performance assessment must be conducted relying on the traditional methodologies such as the LCA.

- A second proposal named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-18: Carbon Direct Avoidance in steel and other metals: Electricity and hydrogen-based metallurgy (IA)"** is instead focused on the steel and metal industries rather than plastic. The idea is to foster researches aiming at introducing or developing technologies in the steel or other metal industries aiming at reducing by 2050 at least the 80% of CO2 emissions compared to those registered in the 1990's. In addition, it is supposed to insert energy and resource efficiency by using renewable energy sources to substitute whenever possible the fossil fuels.
  Concerning those projects for the steel industry, it is necessary to reduce the usage of coal and energy identifying alternative technological and green pathways. For instance, it is expected to substitute fossil carbon with hydro, solar or wind electricity.
  Concerning the non-ferrous metals sector, the objective is to reach a reduction in greenhouse gases emission of the 81% with the goal to decarbonise Europe. This requires new energy efficiencies furnaces, technological advancements, introduction of bio-based energy and bio-feed.

- A third call named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-19: Improvement of the yield of the iron and steel making (IA)"** is focused on the sustainability of the iron and steel making sectors.
  The goal is to validate the efficiency of technologies of impurity removal from scrap and those for the recovery of metal to increase the recycling rate of metal recovery. Indeed, it is necessary to upgrade the quality of scraps to allow the reusability and reduce the environmental impacts by reducing the CO2 emission up to 20%. So new technologies for scrap impurity removals must be developed, and smart sensors and dedicated big data analytics need to be inserted to optimise the decision support system for helping steel plant operators to increase the process yield and augment the quality of products.

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- The last proposal under this topic is named "**HORIZON-CL4-2021-TWIN-TRANSITION-01-20: Reducing environmental footprint, improving circularity in extractive and processing value chains (IA)"** and it aims to increase access to primary and secondary raw materials which a special attention on the so-called critical raw materials for European industrial value chains and European strategic sectors. The goal is to reduce the environmental impacts of extractive and processing value chain by increasing their circularity, to develop methods technologies and processes for mining and processing mining with the intension to reduce the emissions.

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4 Materialising Circular Economy in the Manufacturing Sector

In the last decades the consciousness and awareness about the need to modify the traditional unsustainable behaviours of companies and people, especially considering the environmental and the social spheres of the sustainable development concept (WCED, 1987), started to gain momentum due to the intense growth of resource consumption (OECD, 2019). To be more precise, multiple actions have been proposed and promoted to cope with this issue, and among all it emerged the need to identify new promising solutions to go from linear business models to circular ones to keep as much as possible the value of the resources extracted and used (Garza-Reyes *et al.*, 2019).

Resource circularity concept takes its place within the Circular Economy paradigm. This term started to be diffused almost all over the world quite recently while the concepts behind this paradigm are quite old. Indeed, Circular Economy has been recently defined as "*an industrial economy that is restorative and regenerative by design*" (The Ellen MacArthur Foundation, 2013). Therefore, its concrete diffusion has been highly supported by the awareness created on the society as a whole by the Ellen MacArthur Foundation through its speeches and concrete actions stimulating people to react to create a sustainable world.

Actually two main cycles traditionally characterise this economy: biological and technical as reported in the Figure 9 depicted below taken from (Ellen MacArthur Foundation, 2015):

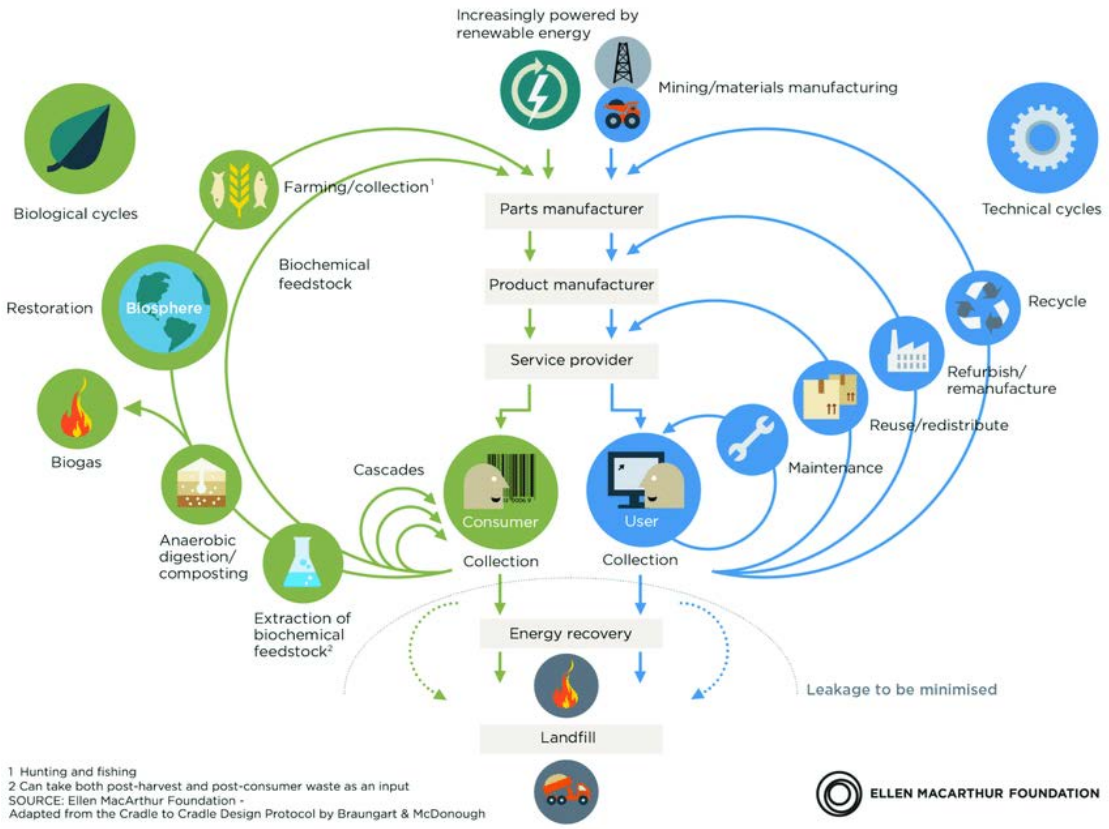

Figure 9 Butterfly Diagram from (Ellen MacArthur Foundation, 2015)

These two cycles are driven by three pillars (Ellen MacArthur Foundation, 2015):

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1. **preserve and enhance natural capital**: *by controlling finite stocks and balancing renewable resource flows – for example, replacing fossil fuels with renewable energy or returning nutrients to ecosystems.* This takes place at the top of Figure 1 since the goal is to identify substitute material and resources to be inserted in the cycles to be more sustainable.

2. **optimize resource yields**: *by circulating products, components, and materials in use at the highest utility at all times in both technical and biological cycles – for example, sharing or looping products and extending product lifetimes*. This takes place at the middle of Figure 1 since at that level the cycles to regenerate the resource are performed.

3. **foster systems effectiveness**: *by revealing and designing out negative externalities, such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use.* This takes place at the bottom of Figure 1 since the resources that cannot be treated to be inserted in new cycles need to be treated to be disposed and they need to be as few as possible.

Actually, considering the digital revolution that the society is experiencing, these flows, to be more effective are backed by a third flow: the informational one (Valkokari *et al.*, 2019). This requires to guarantee the alignment among different stakeholders (Acerbi and Taisch, 2020c).

Moreover, the principles characterising this paradigm, that direct the adoption of specific business models, have been defined as well by the Ellen MacArthur foundation and they are the following: (1) Design out waste, (2) Build resilience through diversity, (3) Rely on energy from renewable sources, (4) Think in 'systems', (5) Waste is food (The Ellen MacArthur Foundation, 2013).

1. **Design Out Waste: "***Waste does not exist when the biological and technical components (or 'nutrients') of a product are designed by intention to fit within a biological or technical materials cycle, designed for disassembly and refurbishment. The biological nutrients are non-toxic and can be simply composted. Technical nutrients polymers, alloys, and other man-made materials are designed to be used again with minimal energy and highest quality retention (whereas recycling as commonly understood results in a reduction in quality and feeds back into the process as a crude feedstock)".*

2. **Build resilience through diversity***: "Modularity, versatility, and adaptability are prized features that need to be prioritized in an uncertain and fast-evolving world. Diverse systems with many connections and scales are more resilient in the face of external shocks than systems built simply for efficiency throughput maximization driven to the extreme results in fragility. 'Natural systems support resilient abundance by adapting to their environments with an infinite mix of diversity, uniformity and complexity. The industrial revolution and globalization focused on uniformity so our systems are often unstable. To fix that we can manufacture products with the same flair for resilience by using successful natural systems as models'".*

3. **Rely on energy from renewable sources***: "Systems should ultimately aim to run on renewable sources. As Vestas, an energy company, stated: 'Any circular story should start by looking into the energy involved in the production process'. Walter Stahel has argued that human labour should fall in the same category: 'Shifting taxation from labour to energy and material consumption would fast-track adoption of more circular business models; it would also make sure that we are putting the*

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efficiency pressure on the true bottleneck of our resource consuming society/economy (there is no shortage of labour and (renewable) energy in the long term)'".

4. **Think in 'systems'***: The ability to understand how parts influence one another within a whole, and the relationship of the whole to the parts, is crucial. Elements are considered in their relationship with their infrastructure, environment, and social contexts. Whilst a machine is also a system, it is bounded and assumed to be deterministic. Systems thinking usually refers to non-linear systems (feedback-rich systems). In such systems, the combination of imprecise starting conditions plus feedback leads to multiple, often surprising consequences and to outcomes that are not necessarily proportional to the input.*

5. **Waste is food***: On the biological nutrient side, the ability to reintroduce products and materials back into the biosphere through non-toxic, restorative loops is at the heart of the idea. On the technical nutrient side, improvements in quality are also possible; this is called upcycling.*

Despite the recent diffusion of this principles under the term Circular Economy, some pioneers started to think about a new society where resources could be recirculated dating back to the 1970's.

- Regenerative Design;
- Performance Economy;
- Cradle to cradle;
- Industrial Ecology;
- Biomimicry.

Regenerative Design: "*Regenerative design means replacing the present linear system of throughput flows with cyclical flows at sources, consumption centers and sinks*". John T. Lyle. John T. Lyle, a landscape professor, was inspired by the theory of Robert Rodale about regenerative agriculture and started to think how to apply it to all the systems without being limited to agriculture. In 1970s launched a challenge for graduate students asking them to think about a society in which the resources usage for daily activities is limited to the available renewable resources, so without compromising the environment. In this way, all the systems could be managed in a regenerative manner that means to establish processes which themselves renew or regenerate the sources of energy and materials that they consume. (The Ellen MacArthur Foundation, 2013)

Performance Economy: Walter Stahel, a Swiss Architect graduated in 1970s, in his Product-Life Institute, a consultancy devoted to developing sustainable strategies and policies, promoted four goals: product-life cycle extension, long-life goods, reconditioning activities and waste prevention. The goal is to sell performances rather than goods. "*Performance economy is knowledge-based and uncouples wealth from resource throughput*". (The Ellen MacArthur Foundation, 2013; Stahel and Clift, 2015)

Cradle to cradle: Michael Braugart and Bill McDonough, authors of "*Cradle to Cradle: Remaking the Way We Make Things*", developed and promoted the certification process of the cradle to cradle design philosophy. The aim is to make companies enable to design product for effectiveness, which implies to design product components to enable their continuous recovery and reutilization as biological and technical nutrients. (The Ellen MacArthur Foundation, 2013). Currently, a certification named C2C has

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been developed to check the characteristics of products throughout different dimensions: (i) material health (e.g. use chemical safe components), (ii) material reuse (e.g. design a product with reused materials), (iii) renewable energy and carbon management (e.g. use renewable resources to manufacture products), (iv) water stewardship (e.g. protect water waste), (v) social fairness (e.g. design business operations that honor people and natural systems) https://www.c2ccertified.org/get-certified/product-certification.

Industrial Ecology: Roland Clift, a Chemical Engineer, put the basis for the industrial ecology that is the study of the material and energy flows through industrial systems. Industrial ecology aims to study the impacts that industrial activities have on natural resources to evaluate how these systems interact with the external environment and the bio-sphere. In particular, under this approach it is possible to create and design closed-loop processes, in accordance with local ecological constraints, in which waste serves as an input, eliminating the undesirable by-products. (The Ellen MacArthur Foundation, 2013)

Biomimicry: Janine Benyus, a biologist, author, innovation consultant, and co-founder of the biomimicry institute, defined this approach as a new discipline to innovate by studying nature, with the goal to replicate and imitate the nature "best ideas" to solve human problems (https://biomimicry.org/). Relying on the three principles which consider nature as: (i) a model to emulate; (ii) a measure to judge our innovation; (iii) a mentor from which learn. (The Ellen MacArthur Foundation, 2013)

Considering the principles characterizing Circular Economy, this paradigm is considered a great driver for sustainability especially for the manufacturing sector (Geissdoerfer *et al.*, 2017) and in this context it takes also the name of Circular Manufacturing (Acerbi and Taisch, 2020a). To be more precise, the regeneration of resources happens though different strategies, also called circular manufacturing strategies, which if concurrently adopted allow to support the sustainable development of manufacturing firms. These strategies might have impacts on different levels among which the micro (e.g. product, firm), meso (e.g. network of firms) and macro (e.g. nation) level proposed by (Ghisellini, Cialani and Ulgiati, 2016) and are reported below in Table 1 taken from (Acerbi and Taisch, 2020b).

Table 1 Circular Manufacturing strategies definitions from (Acerbi and Taisch, 2020b)

Reuse	This strategy, once analyzed the product status and condition, aims to plan and perform all the activities and processes enabling to reuse the product directly at the end of its life cycle (e.g.(Liu *et al.*, 2018))
Remanufacturing	This strategy aims to plan and perform all the activities and processes required to restore a used product in compliance with its original quality, specifications, performances, and warranty (e.g. (Sitcharangsie, Ijomah and Wong, 2019))
Recycling	This strategy, through chemical and physical transformation processes, aims to reuse the components or materials by reducing resources consumption and pollution generation (e.g. (Zhong and Pearce, 2018))
Disassembly	This strategy aims to define and perform all the activities and processes to disassemble in sub-components and materials the product and, under

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	CE perspective, this strategy enables to easily recycle or reuse the single parts (e.g. (Favi *et al.*, 2019; Marconi *et al.*, 2019))
Circular Design	This strategy aims to plan and perform all the activities to be done at the design phase of the product life cycle in order to prevent excessive resource consumption. This strategy eases end-of-life circular practices such as disassembly and thus, recycling, reuse and remanufacturing (e.g.(den Hollander, Bakker and Hultink, 2017))
Cleaner Production	This strategy, being based on product optimization, input substitution and sharing of renewable and recyclable resources, enables to limit resources consumption and toxic substances used in the production processes (e.g. (Sousa-Zomer *et al.*, 2018))
Material Efficiency (Reduce)	This strategy aims to plan and perform all the activities and processes to optimize material used along the production process and product usage (e.g. (Choi, Thangamani and Kissock, 2019))
Waste Management	This strategy corresponds to all the activities and processes required to dismantle waste generated by manufacturers by also handling hazardous waste (e.g. (Rapsikevičienė, Gurauskienė and Jučienė, 2019))
Servitization (Product-Service system)	This strategy aims to plan and perform all the activities and processes to sell a service by using a product as a means. It uses both tangibles (products) and intangibles (services) to satisfy final customers' needs by limiting resources consumption (e.g. (Bocken *et al.*, 2017))
Closed-loop supply chain/ Reverse Logistics	This strategy aims to plan and perform all the activities to establish reverse flows of resources along the supply chain (e.g. (Lapko *et al.*, 2019))
Industrial Symbiosis/Industrial Eco-Parks	This strategy refers to the physical exchange of resources as materials, energy, and by-products among industrial actors that do not belong to the same supply chain (e.g. (Domenech *et al.*, 2019))

Especially, at the management studies the concept of business models is often utilized when there is a need to highlight how the business logic is changing from linear to circular economy. The difference as well as the interlinkage between the strategy and business model is, that a business model provides a way for managers to analyse and communicate the strategic choices. Furthermore, business model provides a link between the strategy and operations/processes and enables exploitation of entrepreneurial opportunities. Thus, the CE business models identified in the literature are closely linked to strategies presented at the table above. For instance, the circular design strategy can be implemented with different CE business models, i.e. saving resources through *renewability* of materials, enhancing use of products through *sharing platforms* or *product as service models* as well as designing for *resource efficiency and recycling*.

Actually the introduction of these strategies in manufacturing companies is driven by the technological advancements which can be either useful to support the physical implementation of specific processes or to

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support the decision making process to select the best option. To report some example regarding the technological physical support, intelligent robotics has been studied as good solution to support the waste management and optimise the required processes (e.g. (Sarc *et al.*, 2019)), 3D printing instead it has been adopted for spare part of medical devices to ensure resource circularity (Unruh, 2018). Instead, regarding the decision supporting technologies, artificial intelligence, internet of things and big data analytics are considered the main means through which selecting the best option for resources circularity in manufacturing (Kristoffersen *et al.*, 2020).

In order to introduce or monitor the introduction of a certain strategy, the performance indicators are also adopted by manufacturers according to what scholars studied. In particular, these models and tools allow to take decisions on one side about the most convenient option among the possible scenarios (Vlachokostas *et al.*, 2020) to choose for instance the most convenient investment (Rieckhof and Guenther, 2018), while on the other side to adjust the strategy according to the current performances and results obtained from the introduction (Krystofik *et al.*, 2018).

These types of researches either on technologies or on assessment models are investigated in detail by (Acerbi and Taisch, 2020a) based on the following framework:

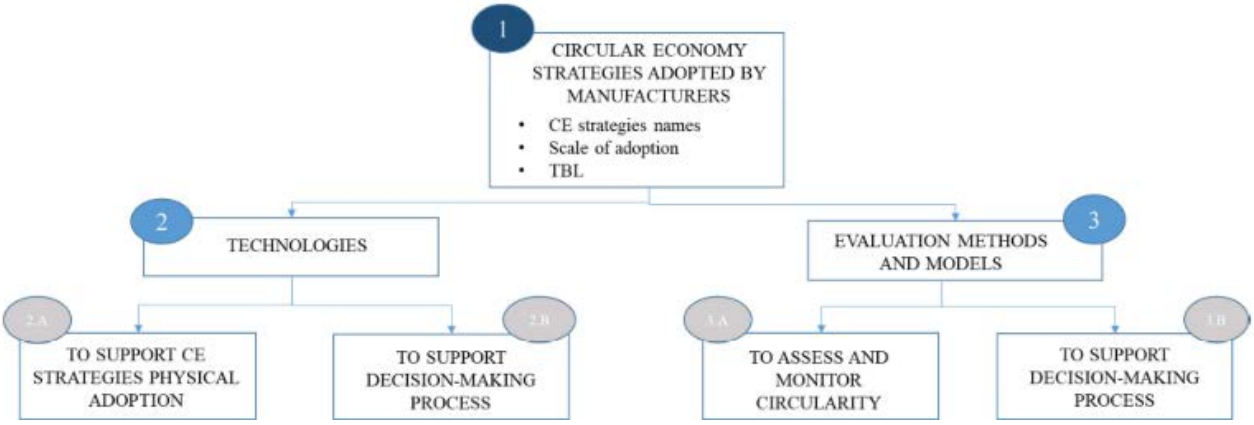

Figure 10 Theoretical framework from (Acerbi and Taisch, 2020a)

The adoption of these strategies is of detrimental importance for the society to address the overarching goal defined by Europe. Indeed, the benefits derived from their adoption of these strategies are almost known and this is the reason why governments, especially the European ones, are trying to boost the undertaken of this direction. Nevertheless, some limiting issues arise when companies face the transition. The main barriers have been studied by scholars among which (Ranta *et al.*, 2018) which explored the barriers comparing the situation in US, China and EU and looking at especially the institutional barriers, (Agyemang *et al.*, 2019) which explored especially the automotive sector with an empirical case study, and (Jaeger and Upadhyay, 2020) which investigated both from a scientific point of view and from an empirical point of view the barriers faced in manufacturing as reported below:

- *Resource-intensive development models: Traditional models are highly resource-intensive; less resource intensive models are lacking*

- *High start-up costs: In the long run, the CE model would show sustainable benefits and increased growth. But, in the short run, the start-up costs are high involving, e.g. retooling machines, relocating*

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factories, building new distribution and logistics arrangements and retraining staff. Lack of budget towards the CE model innovation. Lack of industrial symbiosis is a barrier towards CE because it is costly. Quality assurance for recycled material to be handled in a good manner is costly

- *Complex supply chains: Because production and consumption often take place in different countries, supply chains may need to be reorganised to facilitate reuse and remanufacturing. Incentives throughout the supply chain are needed for companies to actively consider sustainable materials, durability and reparability. For the CE transition, the existing network should support switching between transportation modes*

- *Challenging B2B cooperation: A barrier is coordination across companies because it needs multiple companies to adjust their daily operations. This potentially gives large transaction costs and delays in negotiating among companies. Industrial symbiosis requires information exchange to get knowledge of material and energy flows, which is costly or difficult*

- *Innovation diffusion challenge: It is critical that new breakthroughs rapidly find their way into the mass market so that transition to the CE can contribute to tackling climate- and water-related goals in the necessary timeframe*

- *Structural: Innovation and flexibility are restricted by organisations' hierarchical patterns. CE`s strategies are affected by the managers' employment term restrictions*

- *Contextual: Competition in the market place restricts the movement towards CE Cultural Managers are risk-averse*

- *Restricted supply chain: There is a lack of enablers to improve cross-cycle and cross-sector performance. Lack of exact knowledge of the composition and origin of materials used*

- *Lack of industrial symbiosis: Industrial symbiosis is based on having good knowledge of material and energy flows within an industrial sector and geographical area. It requires an exchange of information regarding inputs and output to optimise the processes, but this industrial symbiosis is a barrier towards CE because it is costly or difficult to obtain*

- *Logistics: Information exchange systems in logistics are limited. Cargo flows are handled by logistics, which also includes the reverse logistics and supply chain management. For the CE transition, existing network design is a barrier. The design should support switching between transportation modes*

- *Lack of information on product design and production: Removing of toxic material and separation of biological from the technical substance is lacking. Shortage of information regarding green suppliers. Current product design is given less attention towards the end phase of products*

- *Recovery: The products are becoming more complex; the recovery of such products is a big challenge*

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- *Recycling: Recycled materials are sometimes more expensive than the new raw materials. Investing in recycling is seen to be risky on a larger scale*

- *Lack of technical skills: A barrier towards the implementation of CE is the lack of skills in small- and medium-sized enterprises. They do not realise the benefit of implementing more advanced technologies that reduce the negative impacts on the environment and would give them costs savings*

- *Quality compromise: Companies' reluctant attitude towards CE is their concern regarding the quality of materials. They fear materials would be chosen based on the environmental aspects instead of the quality of performance*

- *Disassembly of products is time consuming and expensive: A product is made of many different components that are attached in a way that their disassembly is hard and time consuming, and it seems much better to produce a new product than to recirculate the materials, and also it would be very expensive to mould the components in a way they could be available to use again*

- *No surety CE will help the environment: Companies cannot be sure that recycling, remanufacturing and reusing will save money or protect scarce resources, and it might be the case that producing a new product is less costly than reusing the old one*

- *Quality assurance: A barrier is that it is difficult to know what has exactly been done with the material and whether the recycled material is handled in a manner that is good with respect to quality, and all these things involve costs*

- *Design irrespective of CE: The products that are produced lack a circular design, which is the reason the reusing, disassembly, remanufacturing, etc. is hard*

- *Hygienic issues: Some perceive that recycled or reused materials are not safe and hygienic.*

The above mentioned barriers reflect the ambitious goals of Europe to become climate-neutral and the researches stimulated aim to address specifically these barriers to empower manufacturers in becoming circular.

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5 The CF2 Circular Economy pathway

The CF2 Circular Economy pathway rises within the scope of this project to highlight the importance of the Circular Economy paradigm for the sustainable development of the manufacturing sector. The goal is to stimulate the awareness and the consciousness of companies in embracing the Circular Economy paradigm. Therefore, considering that companies need to be guided in the ocean of changes, it has been developed a tool allowing to clarify their current status in addressing the paradigm and to envisage the main areas to be improved within their companies' boundaries and with external stakeholders. The tool is a maturity assessment model which indeed estimates the position of the company in an absolute way considering the levels and the dimensions analysed. In addition, it allows to benchmark this position with the optimum and to compare it with other companies undertaking the same path.

Although it has been adopted as model a maturity assessment model, it is not mandatory for companies to undertake a linear process towards the optimum thus, by passing throughout all the maturity levels, but the process might be disruptive. This is true especially for the new comers rather than for the incumbents which might require bigger efforts for such an internal and external modification.

In the next sections, the model is described in details. Starting first from the structure, thus the levels and the dimensions characterising the model, it is then elucidated the interactive sections held to show the model to a hybrid audience consisting of practitioners and researchers to gather some feedback and validate the model structure and deployment.

5.1 Circular Economy levels and Dimensions

The maturity assessment model developed to evaluate the current maturity levels of companies in Circular Economy adoption is based on 5 main maturity levels covering the 6 analysis of dimensions. The levels and the dimensions characterizing the path constitute a matrix which allows to give the big picture to companies under analysis and to develop tailored suggestions for further improvements (see Table 2 with an example reported). On one side the maturity levels allow to clarify the requirements to embrace this paradigm by highlighting first the need to have an initial internal cohesiveness to finally be able to bring these internal values into the external relationships established with various stakeholders. On the other side, the dimensions allow to clarify the strong areas and those which needed to be stimulated to fully embrace the paradigm by the company under analysis.

Table 2 Matrix for the assessment

		DIMENSIONS					
		PRODUCT	*PROCESS*	*PLATFORM*	*PEOPLE*	*PARTNERSHIPS*	*PERFORMANCE*
LEVELS	*LEVEL1*	FirmA					FirmA
	LEVEL2			FirmA		FirmA	
	LEVEL3						
	LEVEL4		FirmA		FirmA		
	LEVEL5						

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Below are reported the definitions of the 5 levels of maturity characterizing the model, starting from the bottom, thus the lowest level (i.e. “level 1- Linearity”), to reach the highest level, thus the optimum achievable (i.e. “level 5 – Fully Circular”).

LEVEL_1. LINEARITY. The top management of a manufacturing company is stuck into the traditional linear concept of make-take-dispose. It takes care of legal responsibilities related to recycling, waste management and other environmental obligations. It monitors the company performances only to ensure to not encounter additional costs rather than to find new opportunities.

LEVEL_2. INDUSTRIAL CIRCULAR ECONOMY PILOTING. The top management has pushed the experimentation of pilot adoption of some strategies aiming to resource sufficiency (sustainability/circularity) either internally or by exchanging it with external industrial actors.

- There is an attempt to diagnose resource bottlenecks and identify different process parameters. Company operations are monitored by performance indicators which are utilised in evaluation of pilots.
- In order to build awareness and engagement some organizational modifications have been put in place within company boundaries fostered by managerial and tactical levels of the company.

LEVEL_3. SYSTEMIC MATERIALS MANAGEMENT. The adoption of CE is extended to the whole company to find and grasp all the opportunities emerged at least from an internal perspective. The “R-cycles” of industrial materials has become a standard practice adopted by the company in order to systematically identify possibilities to reuse, refurbish, recycle, and remanufacture materials.

- Moreover, any type of resources is internally studied in order to think about their possible reintroduction into (new) R-cycles. At this level, not only the managerial and tactical level is involved but also the more operative one.
- There is an onset of transformational adaptation initiated by local unit leaders to measure and review their own circular performance, and to generate conversations with value chain partners and other stakeholders.
- LCA (life-cycle assessment) is implemented.
- Company is learning to leverage ICT in material management and in achieving competitive edge and for changing desired parts of the operations to more sustainable.

LEVEL_4. CIRCULAR ECONOMY THINKING. Eco-design and Circularity are an essential part of new products and deployment of new services. The company is internally able to re-purpose industrial materials, but further opportunities are found externally. In particular, the exchange of resources with third parties is promoted, through the creation of an industrial symbiosis network, an attempt to establish a closed-loop supply chain is envisaged.

- Data is utilized for boosting new value circles. Value chain level use ICT for tracking, tracing and mapping of resources (data exchange platform) is essential part of the operations.

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- LCA (life-cycle assessment) is a common practice and all the environmental impacts of the production and products are known.
- The intentional transition (CE roadmap considering product, processes, organization and technologies investments areas) is led by managerial and tactical levels.

LEVEL_5. FULL CIRCULARITY. Company has achieved full circularity of products, processes and operations that are sustainable on an environmental, social and economic level. This is accomplished by broad understanding of value flows (such as synergies among forward and reverse logistics, local value chains, zero-waste manufacturing) and co-creation of new value circles within manufacturing networks (like flexible remanufacturing networks, upgrading of products, on demand production) that are key managerial practices.

- ICT is deeply integrated into operations and is highly leveraged. Manufacturing systems proactively prevent excess and reduce rejects and rework through operating on a make-to-order and assemble-to-order basis.
- Wide and versatile partners of the system share a mutual vision for sustaining full circularity and a clear strategy that is being implemented. Managerial, Tactical and Operative levels of the entire company are aligned towards this direction with systematic and proactive follow-up of transition taking years.

The 5 levels above described represent the 5 maturity steps in which a company can be positioned in addressing the parading, and these are defined thanks to an assessment performed on different dimensions. More in detail, the dimensions covered by the tool are also called “6Ps” (i.e. Products, Process, Platforms, People, Partnership, Performance) which are reflected in two main spheres: the technical and the social-business one. The technical one is covered by the Product, the Process, and the Platforms dimensions; while the social-business sphere is covered by the People, the Partnerships and the Performances dimensions (see Figure 11).

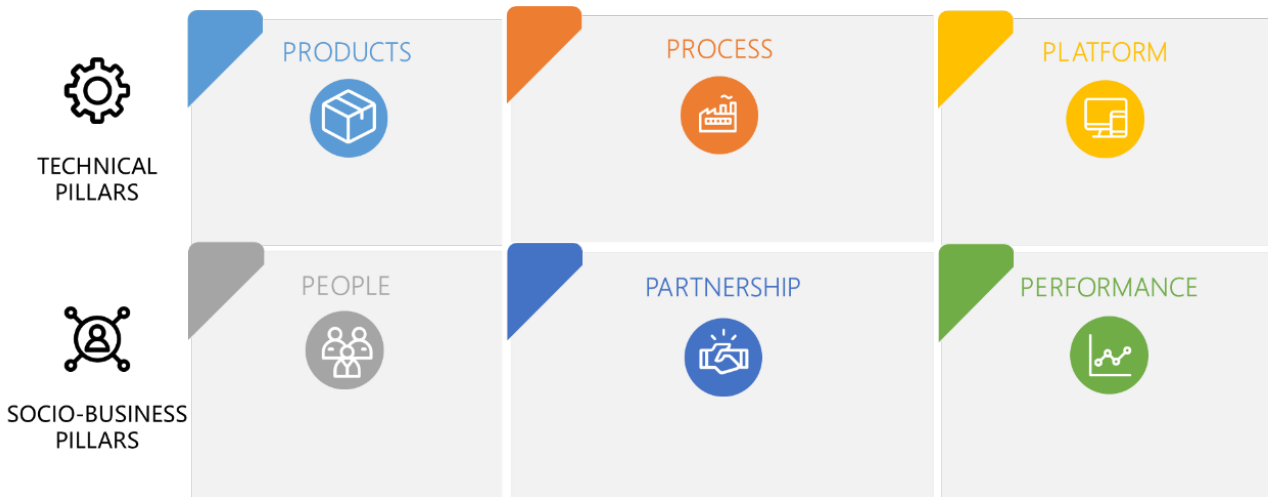

Figure 11 6P framework for the analysis dimensions inspired by MIDHI project

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Below are reported the details referred to each dimension:

- PRODUCT: in the Circular Economy paradigm, the core products traditionally developed and produced by companies need to be innovated and improved to be re-designed to facilitate their circular end-of-life management and to embed CE principles it their features and functionalities. For instance, there is the need to avoid the presence of toxic substances, to reduce the energy consumption during the product production and consumption, to foster the usage of energy from renewable sources etc.

- PROCESS: to embrace the Circular Economy paradigm, several internal processes require to be innovated and improved to go for cleaner production processes and address the resource efficiency requirements. Therefore, it is requested to evaluate how to introduce in the traditional processes, new solutions enabling to respect a lower amount of CO2 emissions during the product production and delivery, to reduce the energy and material consumption during the production by limiting the waste generated, and last, in case would be generated internal waste, to introduce adequate processes to manage it in a sustainable way.

- PLATFORM: the internal innovation of product and processes can be stimulated and supported by the introduction of platforms. These platforms enable to foster an internal alignment and to drive towards the establishment of structured relationships with external stakeholders. Therefore, platforms might be adopted to exchange immaterial and material resources, for instance respectively to learn from best practices adopted by others and to exchange by-products, waste or other material resources.

- PEOPLE: as every transition, new competencies are required to really gain the benefits that would be potentially generated from the adoption of Circular Economy. Indeed, especially for an internal alignment, the transformation towards CE requires the involvement of all the people employed at the different levels and in different departments which need to be trained to improve their expertise and to acquire new skills. New professional roles might be generated and already existing roles might enlarge the spectrum of their competencies.

- PARTNERSHIPS: as just mentioned, the embracement of Circular Economy requires an effort from companies to establish external relationships tailored on the new needs referred to circularity. Therefore, to be successful, the transition requires the involvement of several external stakeholders among which suppliers and customers. These relationships are reinforced in case partnerships are established.

- PERFORMANCES: undertaking the transition needs to ensure to take under control the internal and external transformation by monitoring the related performances. Therefore, the transition requires to be monitored to evaluate potential rooms for improvements and propose continuous update by relying on the assessment of Circular Economy performances.

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5.2 The Circular Economy Pathway Interactive Board (MURAL)

The assessment tool once developed based on the extant scientific literature and past experience and researchers involved, it has been validated through an initial workshop held on MURAL. MURAL is visual collaboration tool, to be used via browser online (MURAL link), which allows the active involvement of several participants during a workshop. It gives the opportunity to ask the audience to share their thoughts and past experience by writing down on virtual post-it what they prefer to share to pave the way for an active and stimulating discussion on the topic.

Therefore, before the workshop, the floor has been prepared to facilitate the discussion among the participants. More in detail, the MURAL has been set in order to create three main moments for discussion. Thus, three main panels have been proposed to the audience: 1) obstacles and challenges, 2) industrial cases, 3) future opportunities.

For each of the three panels were reported on the rows the 6 dimensions defined for the tool while on the columns the 5 levels of maturity. The discussion was led on the columns to verify whether the rows were considered useful by the participants or not and to understand the most relevant elements to be inserted in the updated version of the tool.

To guide the discussion, some examples of post it was reported on the tool and each panel was coloured differently to stick the attention of the audience and to avoid to create misleading discussions. In addition, the different colours facilitated the analysis of the comments after the workshop was finished.

Below are described the reasons why these three issues were discussed and what the expected outcomes.

1. OBSTACLES and CHALLENGES:
   The obstacles and the challenges have been discussed in order to assess what are the main problems faced by the companies when deciding to address a Circular Economy path.

   This discussion should allow to understand the main areas of obstacles to translate then into dimensions of the tool, thus allowing to verify the importance of the dimensions already defined in the tool.

   In Figure 12 is depicted the discussion on the “obstacles and challenges” panel.

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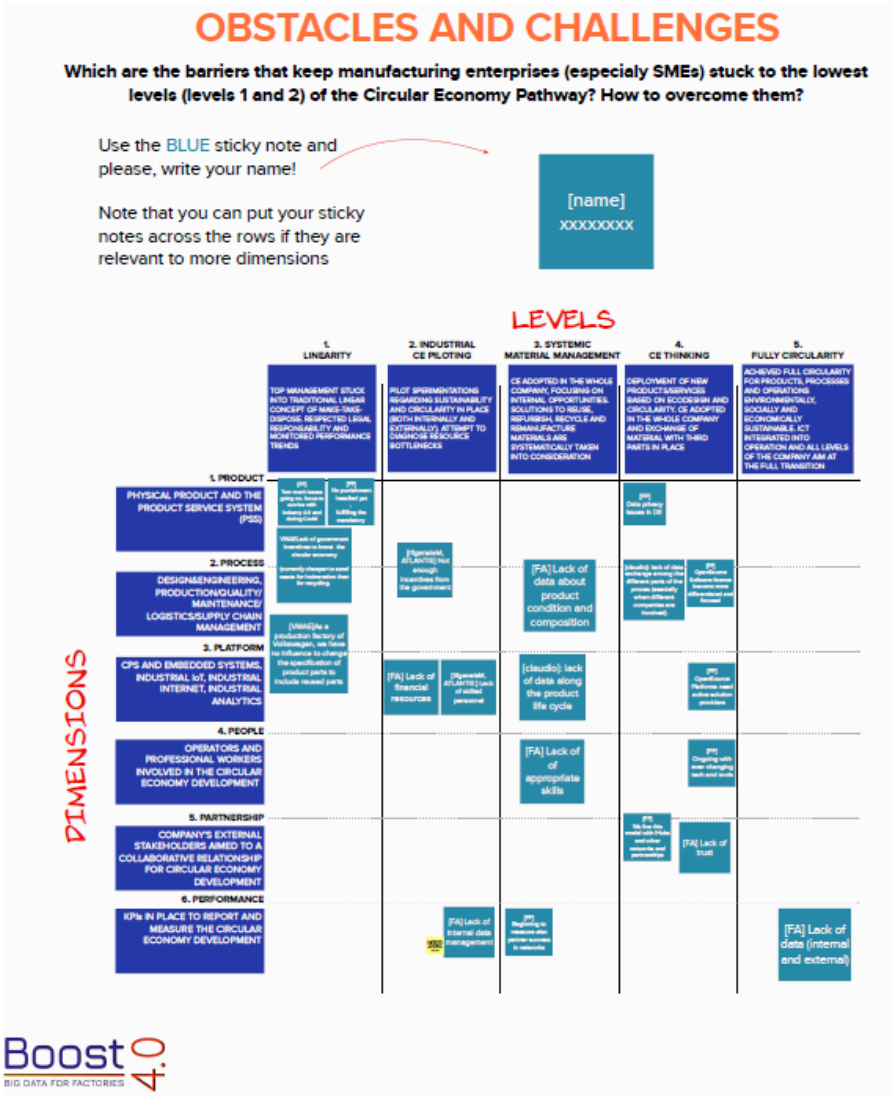

Figure 12 Obstacles and Challenges panel

2. INDUSTRIAL CASES:

The industrial cases need to be discussed in order to create the right awareness to all the participants about the possible best practices to be introduced in their own realities based on past experience of the audience. Actually, the participants were asked to share their experience trying to highlight the level at which the action introduced would have been positioned and what dimensions were involved in the action.

This discussion should allow to understand whether specific steps should be put in practice in order to reach a certain outcome/maturity level or not, and whether the dimension of the tool have been considered in the different actions already put in place by the participants.

In Figure 13 is depicted the discussion around the “industrial cases” panel.

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Figure 13 Industrial cases panel

3. FUTURE OPPORTUNITIES:

The last panel discussed is the one referred to the "Future Opportunities". Therefore, at the end of a great discussion on challenges and the actions to put in practice Circular Economy, the audience is asked to shared their thoughts about future opportunities.

This panel is the last one since the discussion around it is stimulated by the previous panels. Indeed, the audience can think about possible future actions to be adopted according to their current status, by looking at possible maturity level improvement concerning a certain dimension or more than one.

In Figure 14 is depicted the discussion about "future opportunities".

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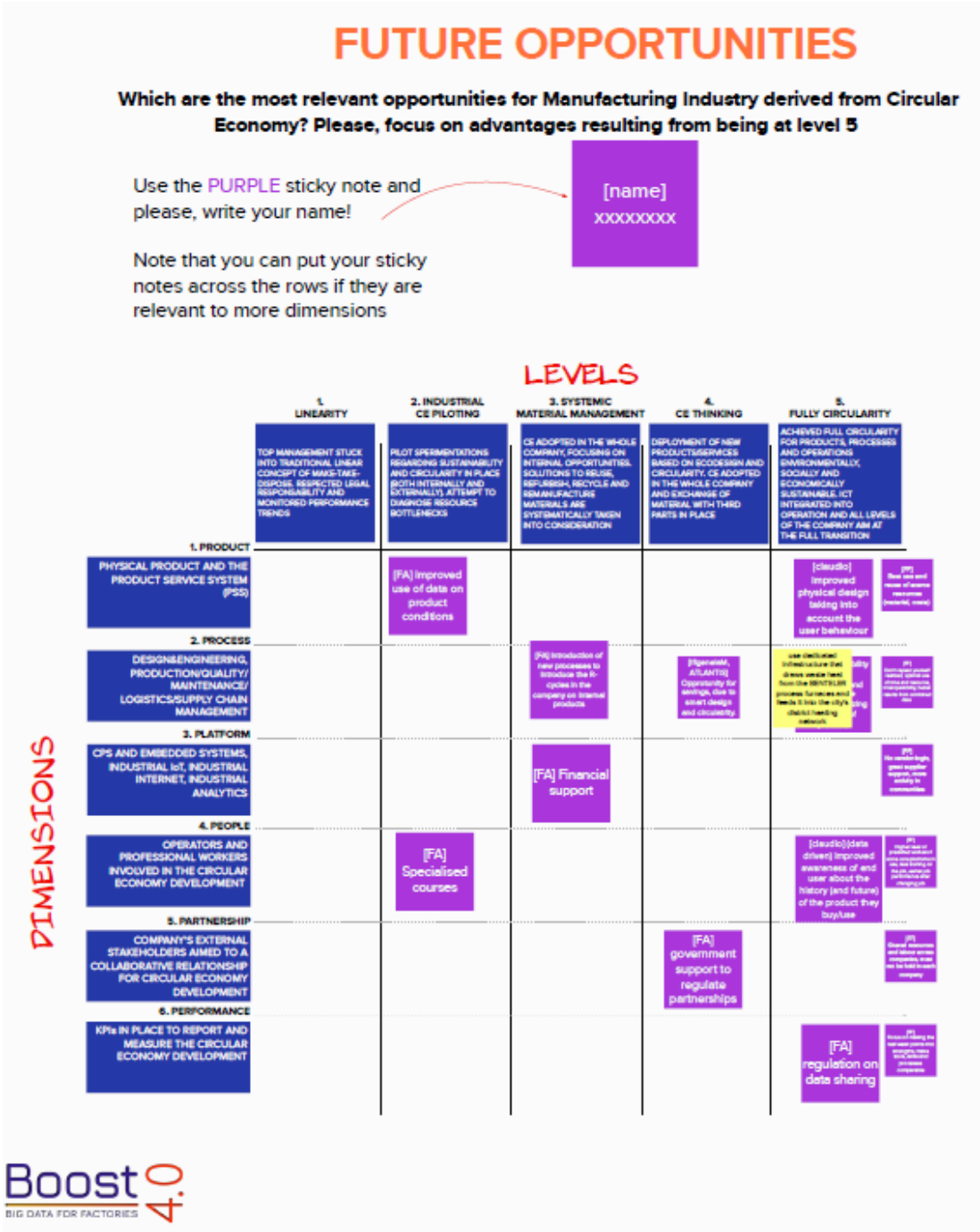

Figure 14 Future Opportunities Panel

5.3 Validation and Experimentation of the Circular Economy Pathway

The assessment tool has been first shown to a hybrid audience of both practitioners and researchers to start the validation process. To be more precise, the partners from BOOST4.0 project as well as variety of Finnish industry stakeholders (including partners of ÄVE project) have been involved in the validation process. Within the both validation groups, it was noticed the circular economy pathway being them highly stimulated by innovation from a digital perspective and might require some more stimulus from a green perspective.

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Indeed, being most of them involved in some small projects or initiatives toward circularity, none of the participants involved was highly advanced in this domain, thus they were considered the right audience to be involved to show the tool and verify its usefulness.

The workshop with BOOST4.0 has been organized via MURAL, as above explained, to involve everyone and make them free to share their experience and thoughts. The participants involved in the workshop already known each other being them part of the same project. This scenario facilitated the initial ice-breaking but it did not bias their replies, instead they actively participated to the workshop by also starting interesting debates defending when necessary the different perspectives. This allowed us to enhance and improve the tool by including different elements coming from different realities.

The participants agreed with the need to involve many stakeholders in the transition, and in doing that data management and sharing was considered as an essential element, but it represents also an obstacle for many since companies usually do not trust in the others and in the usage of their data. Therefore, the partnership element was considered a great driver to cope with this issue and to start approaching to Circular Economy in higher level of maturity. Moreover, everyone agreed with the need to first think internally on how to modify and innovate both their products and processes.

The another workshop with the Finnish stakeholders was organised via MIRO, which is another online collaboration tool, quite similar to MURAL. The discussion topics included development needs, enablers and barriers as well practical examples from the field known as successful CE cases for each level of CE pathway.

In line with the comments from above mentioned workshop, the importance of data utilization as one of the key factors in the transition to a circular economy was emphasized. This might be related to the background of the participants, as several ICT sector companies were involved. In addition, the feedback highlighted the need for concrete examples of development needs and actions at different stages of the path. The highest maturity levels (4 -5) levels were commented to be on too abstract. However, participants identified a few practical examples where circular economy thinking is seen as key part of a company's competitiveness.

Based on the two validation workshops, it can be noted that the developed CE pathway represents the starting point to create awareness in companies and make them start approaching to this innovative pathway in a structured manner. The MURAL online tool clarifies the dimension to be considered and the achievable levels, whereas the MIRO tool was more focused on collecting feedback and case examples. The validation discussions showed as well that benefitting the circular economy strategies is still at the early stage, whereas digitalisation strategies are more concrete at the manufacturing industry companies. Anyhow, the European agenda for twin transition opens a lot new avenues for companies and CE pathway can be further developed as a practical tool to concretise this transition.

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6 Conclusions and Future Outlook

This deliverable, the D2.1 associated to the task T2.1, aimed at clarifying the efforts coming from the DMP cluster, within the CF2 project. In particular, it elucidated how the Circular Economy pathway has been instantiated within the DT-ICT-07 four domains: (1) Agile Value Networks: lot-size one, (2) Excellence in manufacturing: zero-defect processes and products, (3) The human factor: human competences in synergy with technological progress, (4) Sustainable Value Networks: manufacturing in a circular economy.

These four domains are aligned with the emerging needs of the society of stimulating a sustainable development which concurrently relies on both digital advancements and circular systems. Therefore, on one side it is essential to avoid the detrimental consequences that our society would face in case no countermeasures would be put in practice against the uncontrollable usage of planet resources and emissions generation. On the other side, this change can be achieved relying on a digital transformation. This consciousness and awareness needs to be operationalised through concrete actions by manufacturers which require a great support. With this intention, in the "Circular Economy Pathway" a supporting tool has been developed to assess the maturity level of manufacturing companies in terms of circularity. Covering the different dimensions, the 6Ps, the model allows manufacturers to be pro-active in undertaking the twin transition. Indeed, the dimensions cover both the technical and the social aspects addressing the need to develop sustainable systems.

For a manufacturing company, becoming more circular from typically quite a linear operation models of manufacturing networks, there is first need to make strategic decision and consider renewal of its business model and modify its culture moving towards a sustainable attitude and understand the core of the CE principles. Thus at the level of strategic choices and business models, the above mentioned two dimensions (i.e. digital advancements and circular value systems), open several opportunities for manufacturing industry companies. The conceptualisation of the integration of digital manufacturing platforms and CE business models can be presented through the matrix (Figure 15), where different strategic opportunities are positioned.

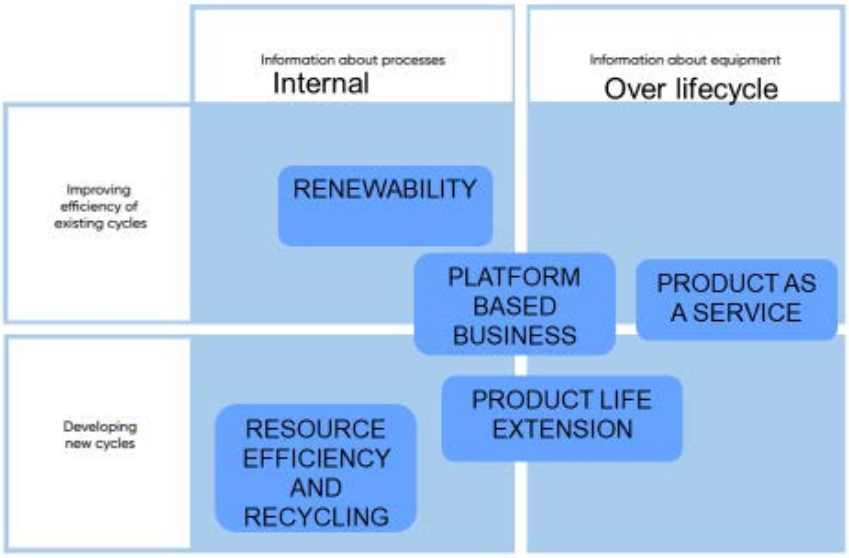

Figure 15 Future Opportunities at the crossroads of digital technologies and circular systems

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Different workshops have already been organized in order to build and validate the tool, nevertheless further works must be performed in order to diffuse this knowledge at European level. Therefore, collecting the practical case examples is an important activity in order to concretise the five maturity levels presented at the CE pathway. At the deliverable D1.2, there is presented a first attempt to position the DT-ICT-07 project activities to the CE opportunities matrix (Figure 15) and thereby deepen the understanding through the practical case examples.

In addition, there is an aim to concretise how the CE pathway and the maturity levels contribute to academic literature. The first step will be a conference paper that will be submitted to the international-conference-advances-in-production-management-systems (APMS2021).

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