DELIVERABLE 2.2

State-of-the-technology (public)

State-of-the-technology: Digital technologies available in different stages of citrus supply chains and best-case practices

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https://impulse-sustainable-supply-chains.net/

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Abstract

In this document we focus on defining the state of the art of a structured group of digital technologies, mainly used in the supply chains of by-products derived from the production processes of juices, beverages and the commercialization of citrus fruits. The structuring has been carried out by determining key actors in the supply chains, from the farmer to the distributor and retailer. These supply chains start in the four pilot countries and end in France and Germany.
As a methodology for adoption, we have used the technology roadmap, which will help us to determine the adoption strategies in the different phases of the process and monitor the results for each case. We propose, in the first instance, to generate a concept of integration along the supply chain, under the slogan of circular value optimization. Under this integration concept, we start by determining that the technologies to be adopted in the chains must consider not only functional and performance aspects, but also environmental and social impacts. These impacts will be aimed at carrying out processes for closing material cycles and making use of waste, as well as technological adoption strategies based on the principles of reuse and remanufacturing, as proposed by the circular economy.
In addition of being enabling technologies for closing loops and producing high quality citrus by-products, these technologies are digital and transmit both performance and on-site condition data, which further strengthen the production monitored management, but as well the distribution efficiency of by-products such as perfumes, nutrients, and medicines. In this sense, we assume that the state of the art contains aspects of innovation, through digitization, but also of sustainability, based on the circular economy.
These circular and digital supply chains will play an important role in the transformation of linear economic systems into circular systems of value management, using waste and the extension of useful life as key performance factors. They will provide, exponentially, better recycled raw materials that will avoid the use of natural sources. They will also contribute to the reduction of emissions, as digitalization will help to coordinate intelligent transport and storage. Additionally, they reduce the usage of energy, by avoiding the adoption of new technologies and supporting a circular modernization that corresponds to reuse and remanufacturing. To close the reading of the state of the art, we propose a benchmarking system, which will help us to research whether the supply chains to be studied behave in a higher or lower degree of optimization with respect to three aspects: 1. Collection and transmission of condition and performance data through digitization. 2. Percentages of value creation and/or recovery based on the production of by-products. 3.The technological adoption within the principles of the circular economy (remanufacturing and reuse), considering regulatory compliance levels and industry standards, which demonstrate quality performance and efficiency.

1 Introduction

The cross-cutting factors of technological implementation and innovation, as a research topic around the supply chains of citrus production and distribution, constitutes the baseline of the current project in its different phases. Our main goal is to build an innovation model based on the Circular Economy principles, to treat waste generated from the citrus fruits and beverages production along the supply chains. Those supply chains originate in the 4 pilot countries (Algeria, Tunisian, Egypt and Turkey) and end in France and Germany, seen as the target market countries.

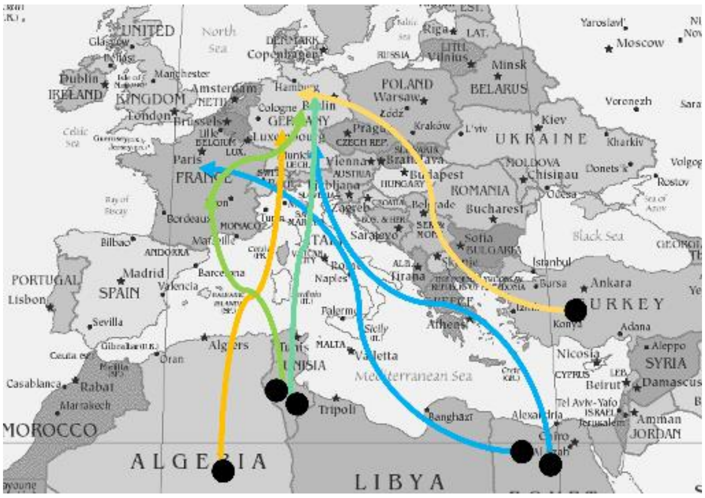

Figure 1: Citrus Supply Chain between four pilot countries, Germany and France [1]

This waste can be transformed into recycled raw materials to produce high-quality by-products such as cosmetics, nutrients, and medicines.

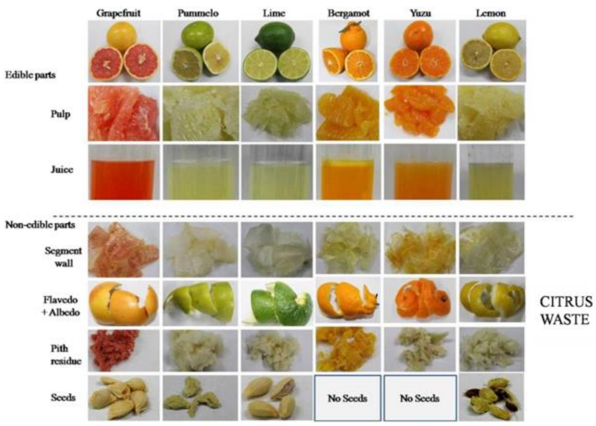

Figure 2: Citrus waste derived [2]

[1] Obtained by: https://www.pngkey.com/detail/u2q8i1w7o0q8u2o0_prco-our-reach-paris-europe-and-north-africa/
[2] Mahato, Neelima; Sharma, Kavita; Sinha, Mukty; Cho, Moo Hwan (2018): Citrus waste derived nutra-/pharmaceuticals for health benefits: Current trends and future perspectives. In: Journal of Functional Foods 40, S. 307–316. DOI: 10.1016/j.jff.2017.11.015.

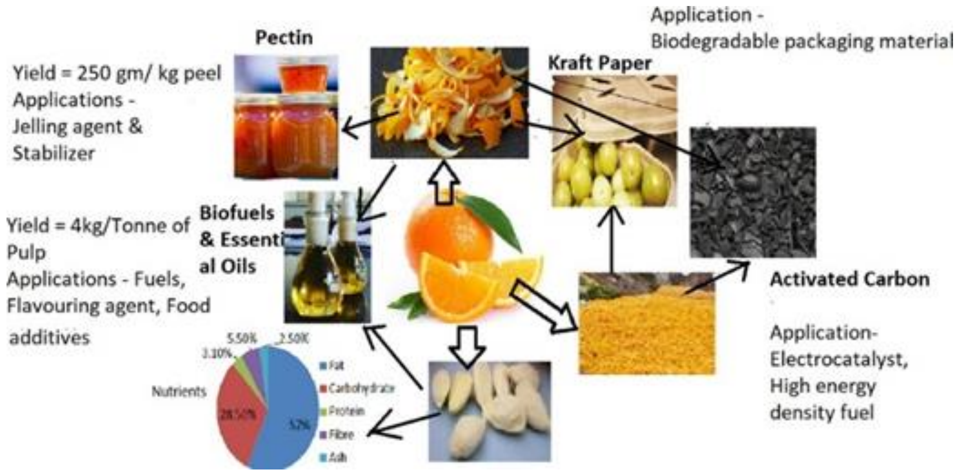

Figure 3: Citrus waste derived [3]

ImPUlSe will consider not exclusively the biological material flows generated in the supply chains, namely seeds and shells, among others, but as well, ImPUlSe concentres on the technical material flows such as packaging materials or more complex products like spare-parts, semi-assembled products or ready-made technologies. The butterfly diagram designed by the Ellen MacArthur foundation, shows us a range of cascading processes for biological but as well for technical material flows, which contribute to optimize resources and enhance value creation along the supply chains.

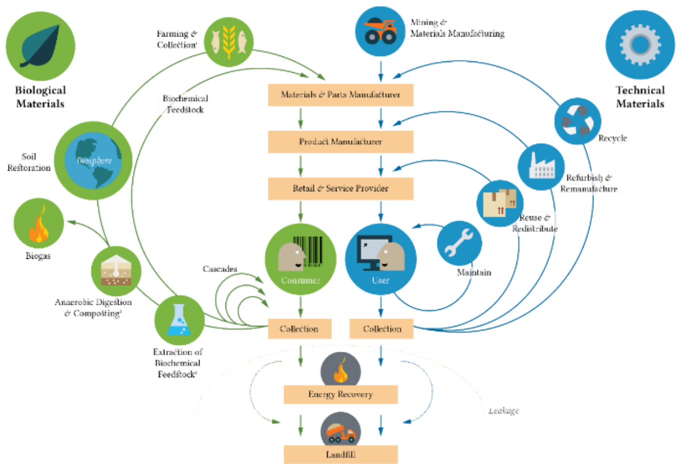

Figure 4: Butterfly Circular Economy Diagram [4]

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[3] Sharma, Kavita; Mahato, Neelima; Cho, Moo Hwan; Lee, Yong Rok (2017): Converting citrus wastes into value-added products: Economic and environmently friendly approaches. In: Nutrition (Burbank, Los Angeles County, Calif.) 34, S. 29–46. DOI: 10.1016/j.nut.2016.09.006.
[4] Ellen MacArthur Foundation (2022): Circular economy diagram. Online verfügbar unter https://ellenmacarthurfoundation.org/circular-economy-diagram, zuletzt aktualisiert am 04.01.2022, zuletzt geprüft am 04.01.2022.

In addressing the issue of innovation and how to transfer it into supply chains between agents that evidence significant gaps (in our case: supply chains composed by stakeholders in Algerian, Germany, France or Egypt for example), both technologically but as well in relation to quality concepts and process efficiencies, it is vital to recognize innovation not only as a separate component in terms of improving those inefficient, obsolete or artisanal processes that can diminish competitiveness, value addressed performance or high compliance. Our approach offers a much more holistic perspective and is aimed at developing models of technology adoption and its corresponding functionality, focusing primarily on a high degree of technology acceptance and functional viability within the framework of the competencies, capabilities, and growth strategies of the productive environments, where it will be adopted.
It is useless to bring any type of innovation in an ecosystem where it could provoke rejections or, even worse, investment drawbacks considering the negative impacts on the purchasing power of the four-pilot countries, seen as the receptive agents of innovation in our research. In this context, ImPUISe, in line with the primary objectives of its proposal, concentrates on formulating models, which holistically incorporate the following key research-based conditions:

1.1 Key Research-based conditions

1. The current project analyses comprehensively the local dynamic technology adoption systems.
2. From that point, ImPUISe maps and characterizes the local manufacturing conditions of citrus products but also the supply chain's performance conditions to fabricate by-products upon the identified technology adoption profiles.
3. As a result of these observations, ImPUISe focuses on highlighting the success factors and barriers regarding implementation around technology adoption associated with the regulatory and socio-technical environments, where those supply chains operate.

Based on these conditions, the current project strives to outline the most viable alternatives for technology appropriation taking into considerations the parameters of value retention and creation by closing sustainably the technological gaps and applying circularity as a key solution ingredient. These components rely on a deep understanding of the technological acceptance levels and the internal processes of strategic planning, in frames of the Investment readiness level scales for each technological appropriation case to be researched.
The basic methodology used to map the technologies and their state of the art, which, from our research observations, should be introduced into those supply chains to optimize production, distribution operations but also value creation in a circular and sustainable form, is

the technology road map [5] [6]. The reason to understand why in this project will be employed a technology road map stems from a discernment of its tools as a methodology and how those tools facilitate to deduce systematically the best type of innovation and technologies in each stage of the supply chain in a close relationship with technology acceptance, viability, functionality and circularity as a set of strategies for value optimization. “Technology mapping is about determining the current technological and competitive position of a company and identifying areas of future investment that will yield long-term competitive benefits.” (Hale Group). The success factors to deploy this value optimization strategy depends on the following research-based assumptions:

1.2 Research-based goals

1. The supply chain agents will be integrated under a single process scheme. This will require transparency, partnership, and participation. The general integration approach will be described as the configuration of ***circular value optimization driven Supply chains.***
2. Awareness raising is fundamental to achieve this integration along the supply chain, from that point of view, we must focus on increasing the level of technological feasibility and acceptance.
3. Technological adoption based on an approach of Life Cycle Thinking (LCT) [7], acknowledged as the basis of the circular economy, will provide concrete solutions to optimize the investments and impacts levels on both logistic and commercial costs generated across the diverse production and distribution processes.

1.3 Challenges for technology adoption

To sum up both the research-based conditions and assumptions under one topic, the current derivable will be highlighting the challenges for a proper technology adoption parallel to the construction of the innovation transfer model, that we implement during this project. The following challenges keep a strong relationship with the strategy to transfer technologies and knowledge but also with the approaches and challenges to be managed in the current project.

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[5] Hale Group (2021): Technology Mapping: Aligning the Technology Portfolio with Strategic Direction. Seen at the 15.09.2021 https://www.halegroup.com/~halegrou/wp-content/uploads/2012/05/Technology-Mapping.pdf.
[6] Moehrle (2013): Technology Roadmapping for Strategy and Innovation. Charting the Route to Success. Seen at the 15.09.2021 https://www.researchgate.net/publication/264237998_Technology_Roadmapping_for_Strategy_and_Innovation_Charting_the_Route_to_Success
[7] Tonioloa, Tosatoa, Gambaroa (2020): Life Cycle Sustainability Assessment for Decision-Making. Chapter 3 - Life cycle thinking tools: Life cycle assessment, life cycle costing and social life cycle assessment, Seen at the 15.10.2021. https://www.sciencedirect.com/science/article/pii/B9780128183557000038

First challenge - a high degree of technology acceptance [8]: One important aspect of the Project is to develop an innovation transfer model, which must contain social, economic, and environmental key issues. Technology adoption also requires transferring technology solutions into practice. From that context, the technology acceptance in its whole extension must be considered as a decisive topic and also as a crucial success factor.

The TAM (Technology Acceptance Model) suggests two levels of technology sensibilization and appropriation: on the one side, it describes the concept around "The Perceived Usefulness" (PU) –defined as "the degree to which a person believes that using a particular system would enhance their job performance". On this regard, functionality and system-compatibility play a very important role in frame of this concept. The second TAM approach addresses the aspect of Perceived ease-of-use (PEOU) – which describes "the degree to which a person believes that using a particular system would be free from effort". In this case, effort means training, investments, complex logistics, but also regulation and industrial standards hurdles.
With a high degree of TA (Technology Acceptance) the innovation and transfer model designed within the frame of the current project will minimize rejections and barriers.

Second challenge - the supply chain integration: ImPUlSe proposes a single concept to integrate the different stages and agents inside the researched certain supply chain This integration process-concept is the construction of ***circular value optimization driven Supply chains.*** The viability, but also the acceptance of this integration concept, embraces a considerable challenge for the technology adoption and the success of the current project.

Third challenge - Measurement tools - Circular economy provides concrete elements to measure performance in comparison to sustainability [9]. Circular economy concentrates on material flows and resource efficiency, those aspects can be concretely measured. But circular economy is currently in an early stage, where indicators and measurement tools are in a probationary status. For that reason, measurement constitutes a very significant factor to build trust and best practice regarding operation and value creation in frame of using circular economy as a research frame. The challenge concentrates on the usability proof of tools and

[8] Chuttur (2009: Overview of the Technology Acceptance Model: Origins, Developments and Future Directions. Seen at 1.11.2021.https://www.researchgate.net/publication/277766395_Overview_of_the_Technology_Acceptance_Model_Origins_Developments_and_Future_Directions
[9] Lavinia (2021): A Critical Review of EU Key Indicators for the Transition to the Circular Economy. Viewed at 1.11.2021.file:///C:/Users/cpinillos/Downloads/ijerph-18-08840-v2.pdf

indicators, which contribute to measure performance and optimization, seeking by this action to consolidate circular economy as an unavoidable process to boost collaboration and value creation strategies.

Fourth challenge - High compliance regarding technology implementation: this project suggests integrating technologies into the supply chain to increase the quality of the recycled raw material production and distribution. In a parallel form, this project introduces a sustainable technology implementation possibility based on circular economy concepts, namely the acquisition and implementation of remanufactured, reused and repaired machines and equipment. This means a considerable challenge, because of a high compliance degree related to regulation and industrial standards, which might be taken into consideration. Hereby, we seek to avoid legal issues and reduce inefficiencies in frames of production and distribution process.
Building on the above challenges, the current document presents below the basic diagram of a technology road map (Figure 5) and its applicability as a tool to design a more comprehensive innovation model designed upon circularity principles.

2 From a basic Technology Roadmap to a Circular Technology Roadmap (CTRM)

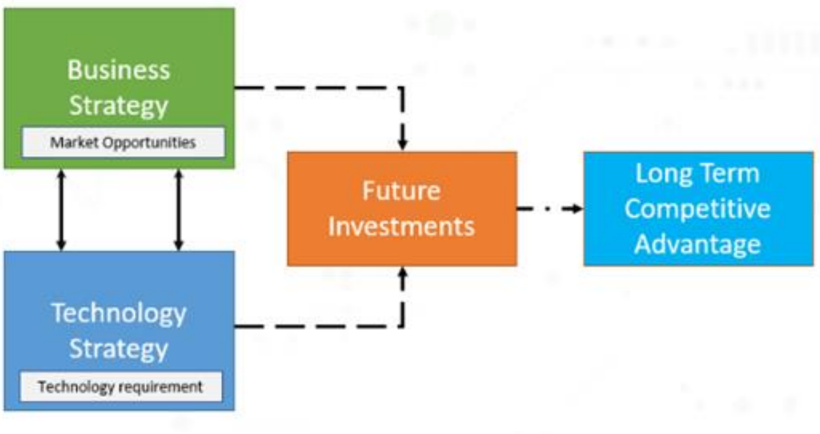

Figure 5: Hale Group Technology Road Map strategy [10]

[10] The Hale Group, Ltd (2004): The Role of Technology Mapping. 19. Aufl. (Strategic Initiatives, 1). Online verfügbar unter http://www.halegroup.com/wp-content/uploads/2012/05/Technology-Mapping.pdf.

The above title means, that the different agents in the supply chain, from the farmer until the consumer, will be analysed through a technology roadmap (considering the four challenges) to identify the enabling technologies, which will allow them to optimize value and carry on a better waste treatment to gain recycled raw materials, basic compound for manufacturing an extensive range of by-products. The comprehensive management to reach that optimization level remains on highlighting the possible cascades (Looping) to reuse and recycle those flows (Biological and technical), previously classified as waste or excesses, which were not treated correctly. In its document *“Circular transition indicators V 2.0 Metrics for business, by business”,* the World Business Council for Sustainable Development (WBCSD) introduces three processes related to technology and innovation adoption across supply chains within the framework of circularity.

Those process are:

1. Close the Loop
2. Optimize the Loop
3. Value the Loop.

With the aim at mapping technologies, that suit the best to the different quality improvement levels to obtain raw materials for the manufacture of optimal by-products and thereby scale the value of the chains, we consider that the process of “Optimize the Loop “is the most suitable at this stage of the research. By focusing on optimization, we will be able to inventory technologies that genuinely contribute to optimize the treatment of these wastes, quantify and qualify them, and if it is possible, collect data directly from the production plants, implementing digital technologies for traceability, smart production and distribution in order to increase agility and competitive advantage for the purpose to commercialize efficiently recycled raw material and high-quality by-products.

The technology roadmap features, beginning from the definition of the basic strategy, which in our case is the harmonization of a circular value optimization driven supply chain, facilitate the selection of the key technologies, which must be used to increase the optimization rates and measure the impacts on the investments and the consolidation of the supply chain long-term competitive advantages. Below, we show the comprehensive development of the integral ***circular technology roadmap***, deployed in the current project.

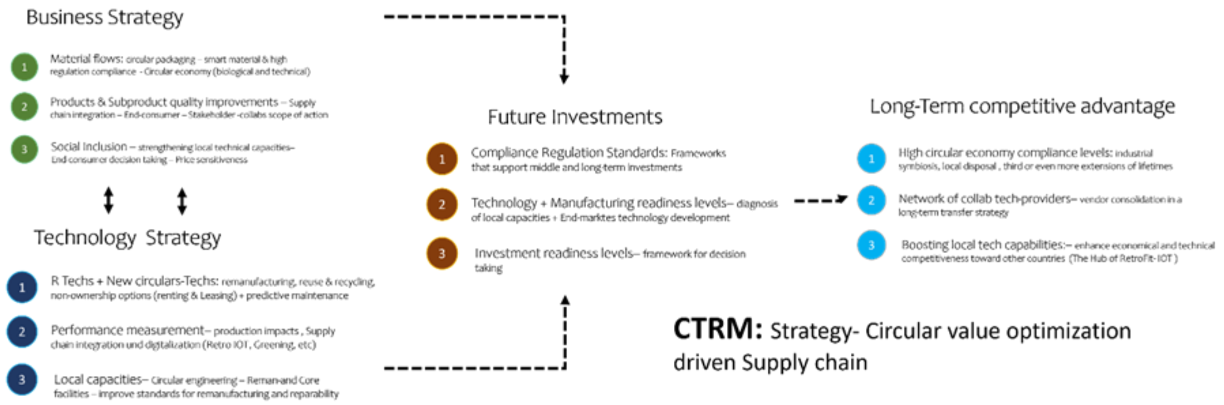

Figure 6: Comprehensive Circular Technology Roadmap 2021 [11]

2.1 CTRM components discrimination

Hereafter, we will explain how we concretize the presented ***Circular Technology Roadmap*** components to choose the required technologies and how those technologies will optimize the value in the high-quality by-products manufacturing supply chains. This CTRM was delineated by resuming the analysis on three key points, with a close relation to each other. The first point of the business strategy is related to the first point of the technology strategy and to the first point of the future investment observations but as well to the first point of the long-term competitive advantage definitions, the seconds to the seconds and the thirds to the thirds, correspondingly.

We begin with the explanation of the business strategy, general described as the *configuration of circular value optimization driven Supply chains,* which is the ground for mapping the enabling technologies to enhance the optimization of manifold production and distribution processes.

3 Business Strategy

We will specify the optimization strategy within its different variants and how this strategy spreads firstly into the technology strategy, consecutively into the impacts related to the future investments and at the end we will observe how competitive advantages are strengthened or created.

[11] Developed by Emporium Partners (2021)

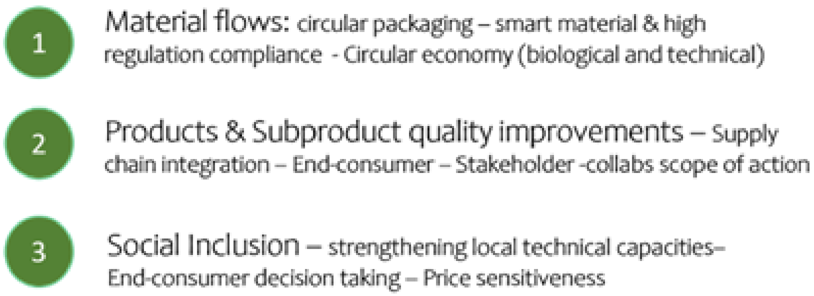

Figure 7: Business Strategy (BS)

3.1 Material flows (BS)

We want to optimize the flow of materials, both biological and technical. This will involve detailing the amount of shells, seeds, another kind of wastes and excesses out-of-date or not able to be consumed or export, but also plastics, packaging material or even more complex technical material flows such as: spare parts, semi-assembled or ready-made technologies. Under the above selected loop optimization process, the formula to be solved in the material flow cases sees as follows [12]:

$$\%\ \text{Critical material} = \frac{\text{Mass of flow defined as critical}}{\text{Total mass as linear flow}} \times 100$$

We must consecutively analyse the materials in the ongoing linear flows, that generate waste or excess; this analysis must be read in terms of % of the critical materials needed to gain recycled raw materials. An example could be exposed as follow: what is the percentage of peels that are generated on a certain citrus juices production to be exported, fabricated in Egypt and distributed in Germany? and under which processes these Peels -biological flows- could be pulverised – what equipment or machines are used – Technical material flows - to obtain a recycled raw material that would allow the nutrients or cosmetics (by-products) fabrication? To select the right elements of studying the percentage of critical materials, we used the methodology of relevance measuring proposed by Mao-Sheng Zhong [13]. This methodology illustrates the process to single out a set of functional indicators according to the

[12] WBCSD (2021): Circular Transition Indicators V2.0 Metrics for business, by business. Seen at the 15.09.2021.http://www.wbcsd.org/contentwbc/download/11256/166026/1

[13] Zhong (2007). A New Method of Relevance Measure and Its Applications. 15.09.2021 https://ieeexplore.ieee.org/document/4460708

optimization goals. After this analytical selection, the following indicators will be employed to determinate the % and usability of the different critical materials:

1. Material Circularity Indicator (MCI)
2. PLCM (Product-Level Circularity Metric)
3. Trade in recyclable raw materials
4. Contribution of recycled materials to raw materials demand [14]

3.2 Products & Subproduct quality improvements (BS)

The above indicators will measure the quantity and quality of the recycled raw material. They are very useful to carry out a proper qualification regarding the cascade-optimization (Recuperation process), which will enable to launch into the market much more attractive by-products in terms of quality and price elasticities. Against this background, we can concretely suggest a range of production and distribution technologies to obtain recycled raw materials and consolidate a buyer and by-product producer network or even, if it is profitable, trying to insource this production task (Recycling to gain raw materials) that process into the main supply chains.

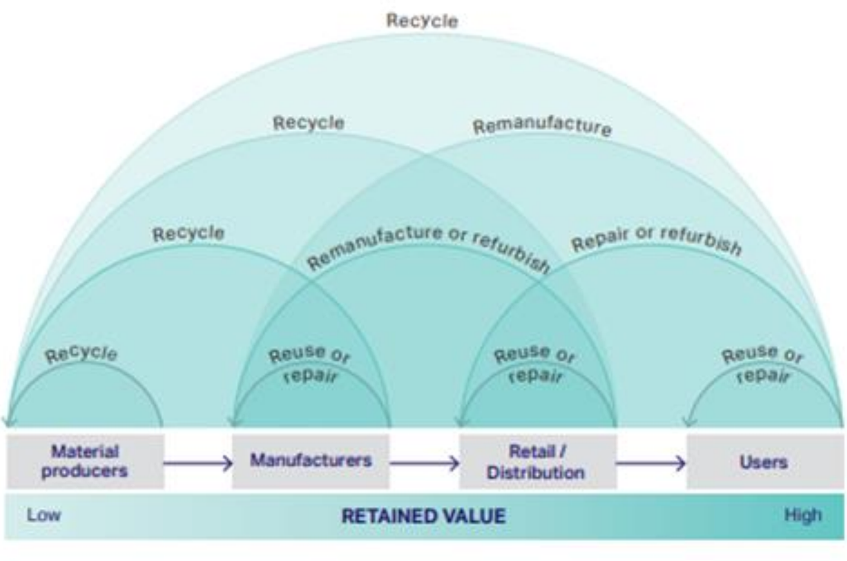

Figure 8 : Recovery types and retained value[15]

[14] Moragaa (2013). Circular economy indicators: What do they measure? 15.09.2021.https://www.sciencedirect.com/science/article/pii/S092134491930151X
[15] wbcsd (2021): Circular Transition Indicators V2.0. Metrics for business, by business. World Business Council for Sustainable Development. Geneva, Beijing, Delhi, London, New York, Singapore. Online verfügbar unter https://www.wbcsd.org/contentwbc/download/11256/166026/1.

Based on the methodology described by the WBCSD, we will define how these materials are recycled and how those cascading-recuperation treatments allow them to retain and scale the value creation at different stages of the supply chain. That is why in the second point of the business strategy we concentrate on describing and qualifying the waste treatment process, using the same methodology proposed by the WBCSD with focus on "optimize the Loop" approaches.

3.3 Social Inclusion (BS)

Social inclusion is of paramount importance. We will not only describe the tasks and actions to leverage up the operators' capacities to handle those technologies, which is the focus on the technology strategy in the current CTRM. In the context of the business strategy, we will rather concentrate on how to appropriate and deploy an integral technological adoption under the approaches of a Life Cycle Thinking (LCT) in combination with a TCO (Total Cost of Ownership) Mindset. As we notice above, all the different agents belonging to the optimized supply chains must actively take part on the same process (Circular value optimization driven Supply chain). They must act in a transparent and harmonized manner to reach the best standards and enhance the value of the recycled raw material and the by-products quality. The impact under the extensible concept of social inclusion on the final consumer will also be considered. The question to be answered is: how to integrate consumers by opening interactive spaces and give them a role in the supply chain? They could be just loyal customers or process qualifiers. End customers must be understood as a key success factor for closing cycles and scaling up value.

4 Technology strategy

At this stage of the CTRM we will focus on highlighting a catalogue of technologies under two approaches.

1. **First approach:** Technologies which should be adopted into the production and distribution optimization systems to gain better recycled raw materials and manufacture high quality by-products.

2. **Second approach:** Technologies that allow us to measure the ***levels of optimization***. On the one side technologies that describe *the quality of the recycled raw materials and by-products (Hyperspectral imaging to choose the best wasted fruits adequate for recycled raw materials)*, and on the other side, technologies which are just focused on

measuring the *quality of production and distribution operations (IoT condition monitoring to measure water or energy consumption during the production)*.

In some cases, we will target technologies already equipped with data collection systems like condition-based monitoring (CbM) remote sensing or technologies exclusively for another kind of data collection like cloud platforms fed with information about economic, social or environmental performance in the frames of a determined supply chain.

Figure 9: Technology Strategy (TS)

To describe the state of the art of those technologies, we prioritize the following two aspects as an implementation scheme:

1. **Best available Technology (BAT)** [16]**:** the best technology state-of-the-art available, without regards for traditional cost-benefit analysis.

2. **Best Practicable Environmental Option (BPEO)** [17]**:** this is a concept introduced by the United Kingdom - Royal Commission on Environmental Pollution (RCEP), which focuses on environmental performance of a certain technology or process. We adapt this concept to define the circular implementation of technologies, like the R-Techs (Reuse, repair or remanufacture), new circulars (technologies produced under standards of eco-design like D4X or Net-Zero) or non-property technology implementations actions (such as renting, leasing and Bailment). This kind of ecoefficiency technology adoption impacts positively the investment level and minimizes the negative environmental effects of producing new technology units with a low compliance of circularity standards.

[16] Conell (2010): Best available technology—a viewpoint on the development and application of the concept to the European non-ferrous industry. Seen at the 16.10.2021. https://link.springer.com/chapter/10.1007/978-94-011-3684-6_39
[17] SEPA (2015): Guidance for the Environment Agencies' Assessment of Best Practicable Environmental Option Studies at Nuclear Sites. 16.10.2021 https://www.sepa.org.uk/media/103546/bpeo_guidance.pdf

With these two implementation schemes focusing on defining the state-of-the-art, we will then describe the step-by-step deployment actions (taken from the Hale Group approach) to map those technologies:

1. **Articulate the business strategy:** as above described, the general business strategy is the configuration of circular value optimization driven supply chains.

2. **Identify the critical success factors:** here we point out two main factors:
   a. One success factor is the result from selected process “Optimize the Loop regarding improvement of quality standards”, which focus on increasing quality on the waste treatment with the goal of gaining recycled raw material and manufacturing high-quality by-product.
   b. And the other success factor is the integration of the whole supply chain under a single process, focus on technology acceptance and scaling up viabilities.

3. **Identify the required technologies:** we signalize technologies that help us to carry out better waste treatment processes but also technologies for measuring the quality of those treatment process (IoT-Condition base monitoring, ERP or CRM cloud platform).

4. **Map existing technologies:** here we identify firstly the best available technologies (BATs) and after that identification, we move to seek BPEOs that better match the purchasing power of the agents, optimize investments and concretely how those BPEOs technologies deploy the needed treatment under environmental approaches. Those technologies will be implemented in frames of R-Tech, new circular or non-ownership operations, which will increase the value optimization supply chain levels under environmental standards.

5. **Sort, Focus and prioritize:** these actions will be observed in the field of future investments and determinate the consolidation of long-term advantage competitiveness, when the decisions take place (acquire technologies or invest on process optimizations).

6. **Manage the portfolio and measure the result:** these considerations belong to the ImPUlSe´s pilot project deployed in work package number 6.

Under the current context, it must be paid attention on the impacts on TCO and production as well as on the marketing of recycled raw materials and by-products. The supply chain must be sensibilized to avoid wrong quality perceptions by producing with R-Techs. This observation complements the circular value optimization approach and will provide a holistic view of value optimization alternatives for both the manufacture process but as well for the technological implementation in terms of improving the investments and closing efficiently the technology gaps.

4.1 R Techs + New circulars-Techs (TS)

In direct correspondence with the first point of the business strategy (circular value optimization in the supply chain), it will be shaped a technology implementation strategy composed by remanufacturing, reuse, repair and non-ownership options, which also match the business models of the circular economy, namely life extension, more services less products, reverse logistics and material recovery. It will be also detailed a set of new circular products described as new products, which apply circular economy principles, such as D4X (designed to be disassembled, remanufactured, and retrofitted). Moreover, it will be identified, if those technologies are equipped or not or can be equipped with CbM like predictive maintenance, which help us to collect on-site data performance.

To reduce the complexity of the catalogue we select a maximum of three technologies per agent. Those technologies will increase the optimization of the supply chain as a whole and improve the raw materials treatment process but also the manufacturing performance of high-quality by-products.
Other technologies to collect data, build communities and consolidate networks like ERP and CRM on cloud systems will be also inventoried.

The following **technology catalogue** contains a specific SWOT analysis per technology implemented at various stages of supply chains with a set of requirements for technology adoption to illustrate the technology implementation viability.

Link to Excel document:
https://uniduede.sharepoint.com/:x:/r/sites/PRIMAImPUISe/Freigegebene%20Dokumente/General/Workplace%20with%20consortium/Deliverables/WP%202/Tecnology%20Catalague.xlsx?d=we6f385a6c895408dbd1f98463f0a96b8&csf=1&web=1&e=T1aQrK

Supply chain Agent	Technology	Images	BATs	SWOT Analysis				Requirements			
				Streght	Weakness	Opportunities	Tread	Integrated Measurement	Viable purchasing power	Closing technology gaps	High compliance performativity
Farmers	**Drones equipped with Multispectral Imaging Pre harvest**		http://agriview.com/multispectral-imaging-camera-drones-in-farming-yield-big-benefits/	Proactive production systems set up, minimizing input and waste cost overruns	Highly sensitive systems that require complex maintenance	Train farmers in efficiency management around drone handling and in parallel introduce training programmes in maintenance and repair.	Not conceive the functionality of the technology in the process of material efficiency (an important solution during harvesting that can be affected by pesticides misuse, germs or environmental conditions).	Optimal connectivity is required to ensure the operation of drones, coupled with a developed system based on the information architecture essential to obtain the required outputs.	Drone technologies are already well established, which can facilitate the implementation of BPOEs.	Precision agriculture is at an early stage. Trainings are simple and interactive, which shortens training times.	These technologies do not have regulatory barriers, but they do have a standard for different industries. This also facilitates the integration of BPOEs into supply chains.
Farmers	**Robotic Weeding - Harvest**		https://www.ecorobotix.com/de/ara_spruehgeraet/	Increase efficiency during harvesting by promoting minimal use of fertilisers and bioremediation elements.	These are high-cost technologies, especially considering TCO factors.	Integrate these technologies with a strong component of direct investment from suppliers dealing with maintenance and spare parts operations	Without an efficient modernization concept, it could easily become obsolete	The technology integrates a quality measurement system for fertilizer quality and use, and can also simulate better soil conditioning	The technology is expensive, basically one could think of new circular or rental systems	The gap can be considerable. If you do not have a spare parts system for the technology, it is quite unfeasible to buy it. Perhaps a TLR 6 would be a viable transfer option	The technology could control the use of fertilizers, as it is so new it is not considered to be a problem in terms of regulation. It would be important to review the level of industrial standardization to consider the real impact of the investment.
Farmers	**Conveyor hyperspectral scanning Post-Harvest**		https://www.pleora.com/markets/machine-learning/ai-and-hyperspectral-imaging/	This technology can transmit data to the supply chain regarding separation processes in an optimal way, determining the volume and quality of recycled material.	Non-compatibility between components could cause problems at the time of installation and commissioning.	Integrate an intelligent system that nimbly interfaces the entire supply chain in a material efficiency exercise.	Quality measurement systems are not well tuned and erroneous data is transmitted.	The technology itself is a quality separation and measurement tool. It is integrated with condition technology for both quality reading and predictive maintenance.	Various components can be found in high quality reuse and remanufacturing.	Apart from the use of chambers, the major gap to detail is the determination of a methodological measurement scheme adapted to what is sought in the chain interactio	No high regulatory complexity is noted and rather the factors of industrial standardization should be considered as decisive in the operation.
Food processor	**Smart Multi Utility Grinding Machine**		https://www.cabe.it/wp-content/uploads/2019/04/Technical-Sheet-Grinding-Machine-SMART-PRO-500.pdf	The technology can measure the materials inputs for pulverization according to industrial quality standards.	An optimal compatibility system would have to be integrated with the production system, as well as high-level training with operatives who can as far as possible maintain the machine.	This technology is ideal for the transmission of data regarding the quality of the recycled raw material, communicating to buyers the type of material and efficiently using other materials for the composition of recycled material.	Under-utilization of the machine due to low optimal volume generation or low collaboration plans with other farmers or food processors	Excellent intelligent metering systems, with multiple data communication and system compatibility.	The technology is expensive, basically new circular or rental systems could be considered	The machine is complex, although the user manuals are clear, maintenance requires high technical capacity.	It becomes important to understand the volumes within the standards to be achieved
Food processor	**NFC connectivity with autonomous sensing, data processing and logging.**		https://apfoodonline.com/industry/smart-packaging-is-creating-new-possibilities-for-beverages/	Maintain traceability of products in this case by-products by integrating the consumer into the supply chain.	Not considering an external traceability system across the supply chain	Increase confidence in the use of materials and quality standards.	The system can be boycotted and information falsified	It is a traceability and information consolidation system. It helps a lot in the geolocation of materials and their consumption.	It would be interesting to integrate a circular system of use, which consolidates an efficient reverse logistics, which reduces the cost of manufacturing new sensors and films.	It is a technology in early stages of use, the gap is considerable, although it is a simple to use, this system requires high administrative operation and orchestration.	This technology is governed by the regulatory system in terms of obligations to communicate or not certain components and product standards.
Food processor	**ERP Clouding**		https://www.sciencedirect.com/science/article/pii/S2314728816300599	It is essential as a platform for communication and traceability of resources, important that it can be used as an element of integration along the supply chain.	Traceability is only carried out at the food processor stage.	Integrate a condition system connected with GPS and IoT to give more 24/7 information on performance from resource efficiency.	The system can be boycotted or hacked	There would be two alternatives: integrating non-condition data with a certain periodicity or collecting data with sensors that transmit performance.	They exist at different levels of investment, also in as-a-service or on-premise systems.	They are widely recognized systems. Models and versions must be verified and how they fit in with production and distribution systems.	There are more than regulations certain standards in input data management and orchestration with outputs for intelligent decision making.
Retailers	**Intelligent display cases**		https://www.archiexpo.com/architecture-design-manufacturer/refrigerated-display-case-30817.html	Smart counters communicate not only stocking but also product quality and traceability to end-users	Information may be false or not harmonized with supply chains.	They generate an interactive channel with consumers, understanding their consumption habits and level of demand regarding quality and sustainability.	The system can be boycotted or hacked	These are measurement systems to deploy efficiency in the supply chain. They measure quantities sold, concentration of purchase intention and convey information on sustainability and good practices to the end customer.	They can be implemented in R-Tech systems by adding smart elements to classic shelves, such as sensors for attention reading or when products are removed from the shelf.	Systems are used in Europe, but they are certainly not interconnected with the whole supply chain, the gap can be closed with participation and collaboration strategies.	Regulations with respect to the customer, who demand transparency systems as well as quality standards.
Retailers	**Prosumer Facilities showrooms**		https://www.benjis.com/	They are communication and active supply management technologies, they can convey supply chain quality concepts in real time and generate proactivity in purchasing and sales in the framework of the supply chain operations.	Failure to convey key concepts and experiences to end-use agents or end-consumers. This could lead to distortion of the messages and concepts that the chain is seeking to establish	These modules interact with the end consumer regarding high quality processes that are being deployed in the supply chain.	Failure to clearly communicate the processes and that would follow to lose value and generate mistrust instead.	The different modules such as digital signage generate an instrument of communication and integration of the consumer with the entire supply chain from the strategic and operational level	There are modules in new circular and remanufactured production systems that could be considered as efficient investments if the supply chain is integrated under a single communication strategy.	This would be part of the retailer's investment, who would have more purchasing power, although the risk could be diversified, as the communication strategy benefits the entire supply chain	It must be reviewed, if the regulation affect the utilization of public spaces such as airports or social hubs and the constrains of information to be transmitted within the framework of sustainability and circularity.
Retailers	**Retail Demand Planning AI-powered recommendations**		https://www.relexsolutions.com/resources/how-to-benefit-from-ai-in-retail-optimization/	RDP platforms work to simulate trade scenarios and different types of disruptions, such as environmental, inflation etc., that supply chains may experience.	Failure to harmonize the chain in terms of system functionality.	Demonstrate an element of management where end-consumers are integrated and actively interact in the dynamism of the chain.	The system can be boycotted or hacked	This is a simulation system, excellent for determining variables of sensible or drastic changes in the chain.	It can be implemented in licenses as a service or on premise.	Basically the gap is in the acceptance of the system and the deployment that might be suggested.	It would be a very comprehensive system that can give an idea of the regulation and circular standards for agents and end customers.

Supply chain Agent	Technology	Images	BATs	SWOT Analysis				Requirements			
				Streght	Weakness	Opportunities	Tread	Integrated Measurement	Viable purchasing power	Closing technology gaps	High compliance performativity
Circular Engineers	**Smart cylinders valves, circuit breakers, and cables**		https://www.cavagnagroup.com/industry-4-0-remote-control-clickclick/	Intelligent gas, material and liquid monitoring devices are a great solution for quickly and efficiently determining the quality and volume of recovered raw materials or material flows.	Compatibility with existing systems can be a major difficulty	Integrating an on-site flow reading system, with different measurement parameters	Failure to standardize them throughout the supply chain.	These systems are focused on flow readings, they can be implemented in the technologies or also in peripherals in relation to the technology.	Sensing elements can be attached to valves or cylinders already in operation	Considerable if not integrated along supply chains	Import of remanufactured products would have to be reviewed due to protectionist regulations.
	Supply Chain Diversity, Equity & Inclusion platform **Regulation Fit platform**		https://gabi.sphera.com/america/index/	Platforms of this style lend a quality and trustworthy character to operations in general. They qualify performance in terms of circularity.	Not being fed with transparency and truthfulness could lead to distortions .	Being able to integrate a system of standardization using regulatory frameworks and industry standards	The system can be boycotted or hacked	The system interprets feasibility and operational as well as financial management of different actions in the supply chain	Can be implemented in licensing as a service or on premise	Interesting to see it as a tool managed collaboratively by the chain to consolidate integration	Customer regulations demand transparency systems as well as quality and integration standards.

Figure 10: List of suggested digital technologies and the state of the art

There are two main aspects to remark on this catalogue. First, consumers will be considered as an active actor into the supply chains accordingly to their free decision to belong to one stage of the chain or be part of a process. They can provide key information in the offered platforms and close material loops depending on which process were habilitated from the agents to include their participation. Their role will be considered deeply in the business strategy under the third point “Social inclusion”. A second factor to highlight is the role of the circular engineers, as agents they are deeply involved in the production and/or distribution lines, but they act transversally in the chains, either by providing equipment and machinery to optimize the cascade operations such as smart cylinders or by standardizing the value circular optimization, through the integration of regulatory or social inclusion platforms.

4.2 Performance measurement (TS)

This point is related to the second point of the business strategy and focuses on the components of measuring the level of quality, both for the reutilization process to gain recycled raw materials but as well on the production process of those raw materials and high-quality by-products. Here the core of the research will be given by the data collection, depending on the relevance and quality of this data. In this sense, we present the following diagram that will help us to clarify the quality of the required data. This is a single part of a diagram, presented on the CTRM final stage regarding Future Investment. This part of the Diagram highlights a focus on measuring, related to the 4 major indicators introduced above.

1. Material Circularity Indicator (MCI)
2. PLCM (Product-Level Circularity Metric)
3. Trade in recyclable raw materials
4. Contribution of recycled materials to raw materials demand-

These indicators will be collected by technologies and provide a number of important key outputs for the current research. Those datasets constitute the baseline to measure the level of loop optimization.

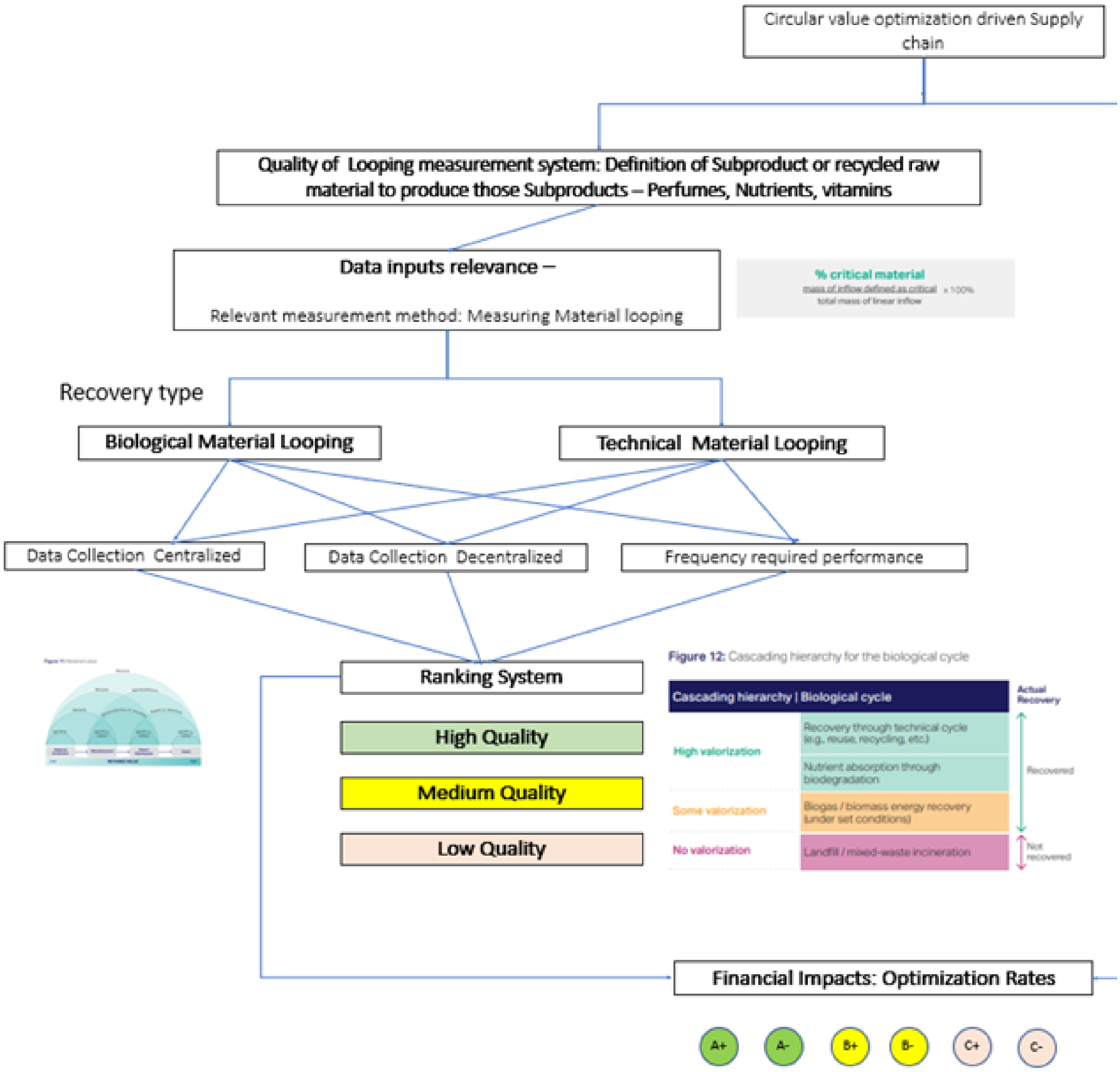

Figure 11: Benchmark system to qualify supply chain performance (closed-loop processes)

If we research a circular value optimization supply chain, it is very important to qualify the cascading operations (Recuperation & Reutilization) as introduced on the business strategy. But it is even more relevant to detail the data which guides to conduct that optimization.

Optimization depends basically on data and the quality definition of that data is fundamental for the success of the optimization. Data performance will be described as following[18]:

1. Data inputs and frequency required
2. Data Collection Centralized & Decentralized
3. Data entry methods
4. Data display capabilities
5. Usability and support
6. Compatibility

This aspect will be studied in terms of the supply chains traceability technologies and will give us an idea of where optimization, reuse and waste transformation into raw materials takes place, and moreover where value retention and creation in frames of the chains operate. It will be identified whether this data is generated centrally, at the production plants, for example through hyperspectral imaging, or whether it is obtained in a decentralized form through platforms externally to the production site. The type of data inputs and frequency will determine the relevance of these data in regard to the standards to be consolidated on a certain supply chain. Frequency will scope the traceability quality and communicate those standardized operations through agile and transparent channels.

4.3 Local capacities (TS)

In the third point of the technology strategy, it is fundamental to set up a TCO mindset in relation with the long-term improvements vision of the technician and operators installed capacities locally. Here we will observe the aspects of training and the existing technical gaps of those technologies' operators.

This aspect will facilitate the selection of actions to be done to increase the level of acceptance and ownership of the supply chain integration strategy, taking into consideration its different elements. If we want to introduce R-Techs, we must then consider the local strengthening through workshops specialized on repairing and remanufacturing processes, since in case of a breakdown or version updating it would be inefficient to return the machine to its point of origin or hire an international technician to repair or deploy maintenance for a certain equipment. Those cases will negatively impact the investment and scalability levels. We will measure how operators could also acquire new skills that prevent them from losing

[18] US Gov (2010): Designing a benchmarking plan. 15.10.2021. https://www1.eere.energy.gov/wip/solutioncenter/pdfs/tap_designing_a_benchmarking_plan.pdf

their jobs and social status due to automation and robotization of production processes, an inevitable factor in the future if we really want to increase the competitiveness of the researched supply chains.

5 Future Investments

To carry out an integral discernment on the field of future investments in frame of the CTRM, we will concentrate basically on two major aspects:

1. The impacts of the investments regarding innovation and the proposed mechanism to adopt technology according to the principles of the circular economy and the existing regulation, industrial standards, and the compliance level needed to support technology adoption under circular principles for each agent in the supply chain. That concerns the observation if there is a beneficiary regulation to promote circular economy actions like the transformation from linear to circular business models or even more important the possibility to import remanufacturing technologies, which allow the agents to close cost-efficiency technology gaps under the approach of BPEO circular strategies. Regulations or not accepted standards can undermine the entire strategy of a configuration of circular value optimization driven supply chains.

2. When we resolve the regulation, standards acceptance, and feasibility, then we can define the levels of compliance of the supply chain. That bring us to configure a variety of performance ratios between purchasing powers on each stage of the supply chain and the possibilities to yield a set of price elasticities according to level of the needed competitiveness. We want to promote sustainable investments based on processes like the linear to circular transformations, eco-efficiency technology implementations, cost-benefits and price transparency configurations for recycled raw materials as well as the production and distribution of high-quality by-products. All these actions will enable the design of circular value optimization driven supply chains.

Figure 12: Future Investments

An example can clarify this approach:

We are to examine if there is a barrier to import R-Techs into Egypt or observe which are the local perceptions or industrial standards by using R-Techs. If there is any kind of barrier (in this example) and they act locally with high industrial standards even with R-Techs, then we can define if the observed agent can acquire the existing and selected BPEO, and consequently, we could simulate a price elasticity model to configure optimal prices for recycled raw material and by-product.

The underlined situation is: The integrated agents have reduced their technologies investment costs and therefore they can be more competitive with lower prices and high-quality products.

5.1 Compliance Regulation Standards (FI)

As already introduced, we will define the level of compliance by establishing the relations between existing regulation and the levels of acceptance regarding industrial standards. This point of the CTRM maintains a close relationship with the first points of the business and the technology strategies because it is aimed to introduce an optimization process in the supply chain, and from that context, it will be described what is the feasibility in regard of regulation and standards to back up the arguments for an optimal investment decision taking.

Secondly, we want to introduce R-Techs, new circulars and non-ownership technologies schemes, and if the local regulations and standards set up barriers that could cause difficulties, that will affect the operations of the circular value optimization driven supply chains. In this context we will look at how in the pilot countries and final destinations Germany and France the circular economy has been integrated and promoted, either as a national strategy or as a regulation that supports the transformation from linear to circular business models (supported with tax benefits, financing green credits and/or state support grants will be detailed). Key aspects such as the description of the extension of producer responsibility obligations, regulation and industrial standards for remanufacturing technologies, the right to repair, among others aspect of regulation and industrial standards will configure the compliance frameworks and give feasibility of the needed investment to success with the presented business strategy.

The following topics are the most important regulatory fields, related to circular economy and provide frames for sustainable investment, regulation standards and compliance levels:

Regulatory fields

1. Energy consumption during production and distribution
2. Eco-design: right to repair
3. WEE (Waste of electronic and electric products) protocols and regulation
4. Import of R-Techs and non- Ownership
5. Export of R-Techs and non- Ownership
6. Warranty systems
7. Extended producer responsibility
8. Raw material declaration
9. CO^2 regulation (Netzero)
10. Local market protection

We will apply an analysis for each country to determine the success factors and barriers for investments and value optimization in terms of improvement processes and circular technologies implementation for the required technologies and in a concrete manner to define the compliance levels of each agent and the entire supply chain.

These are the used tables to understand the feasibility level after studying the regulatory fields in each pilot country.

Table 1: Regulation Qualifying items

Success Factor	Turkey		
	Excellence	Acceptable	Deficient
Collaboration			
Regulation			
System Compatibility			
Installed Capacities			

5.2 Technology + Manufacturing readiness levels (FI)

The relationship between TRL and MRL (Manufacturing readiness level) will illustrate concretely the fields of investment to be considered. We will focus on describing the concrete TRL in which a certain technology is located and upon that note in which MRL that technology is used locally. This observation will specify the level of technology acceptance and functionality as a relevant component of the technology adoption levels. For example, we found a technology in Germany with a TRL 7 - First implementation - and in Egypt that technology is already introduced with a MRL 8 – Pilot line capability demonstrated. Under this scenario we can manage cost-benefits strategies and propose pilot collaborative transfer projects between providers and end-user to reduce investments and consolidate future interchange relations. When those aspects are defined, we can configure ratios between purchasing power and price elasticities to back up negotiations and simulate cost-benefits scenarios around the manufacturing of recycled raw material but also production, distribution cost and price configurations of high-quality by-products.

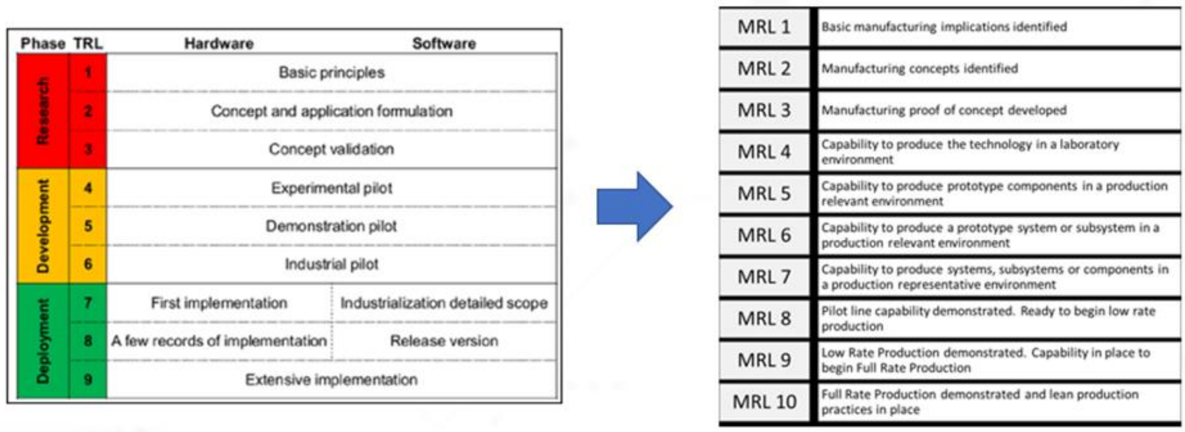

Figure 13: Technology Readiness Level (TRL)[19] and Manufacturing Readiness Level (MRL) [20]

5.3 Investment readiness level (FI)

To close the field of future investments, we will focus on the impact of investments and the level of scalability of those investments for a successful circular value optimization strategy.

[19] Nasa (2012): Technology Readiness Level. Online available under https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level
[20] Santos, Isa (2013): Product development methodologies. Online available under: https://www.researchgate.net/publication/257652377_Product_development_methodologies_the_case_of_medical_devices

Figure 14: Investment readiness level (IRL) scale [21]

These nine levels of investment readiness level are the key to define the amount of investments, and to detail concretely how these investments will influence the innovation and technology adoption processes in term of optimization and sustainability. In this sense, we will then be able to determine, based on the two aspects introduced in the First point of the future investment of the current CTRM (Compliance Levels in regard to regulation and industrial standards), whether the chain generates value optimization and what would be the impacts of the investments on the optimization from a circularity perspective. For this purpose, we will implement an Analytic Hierarchy Process (AHP) [22] that will help us to build a system of Benchmarks and rankings to define the final rates of investment optimization and the financial impacts obtained from the implementation of circular processes.

[21] Blank, Steve (2014): How Investors Make Better Decisions: The Investment Readiness Level. Online available under://steveblank.com/2014/07/01/how-investors-make-better-decisions-the-investment-readiness-level/.
[22] Singh (2015): An analytic hierarchy process for benchmarking of automobile car service industry in Indian context. 14.10.2021.https://www.researchgate.net/publication/276487726_An_analytic_hierarchy_process_for_benchmarking_of_automobile_car_service_industry_in_Indian_context

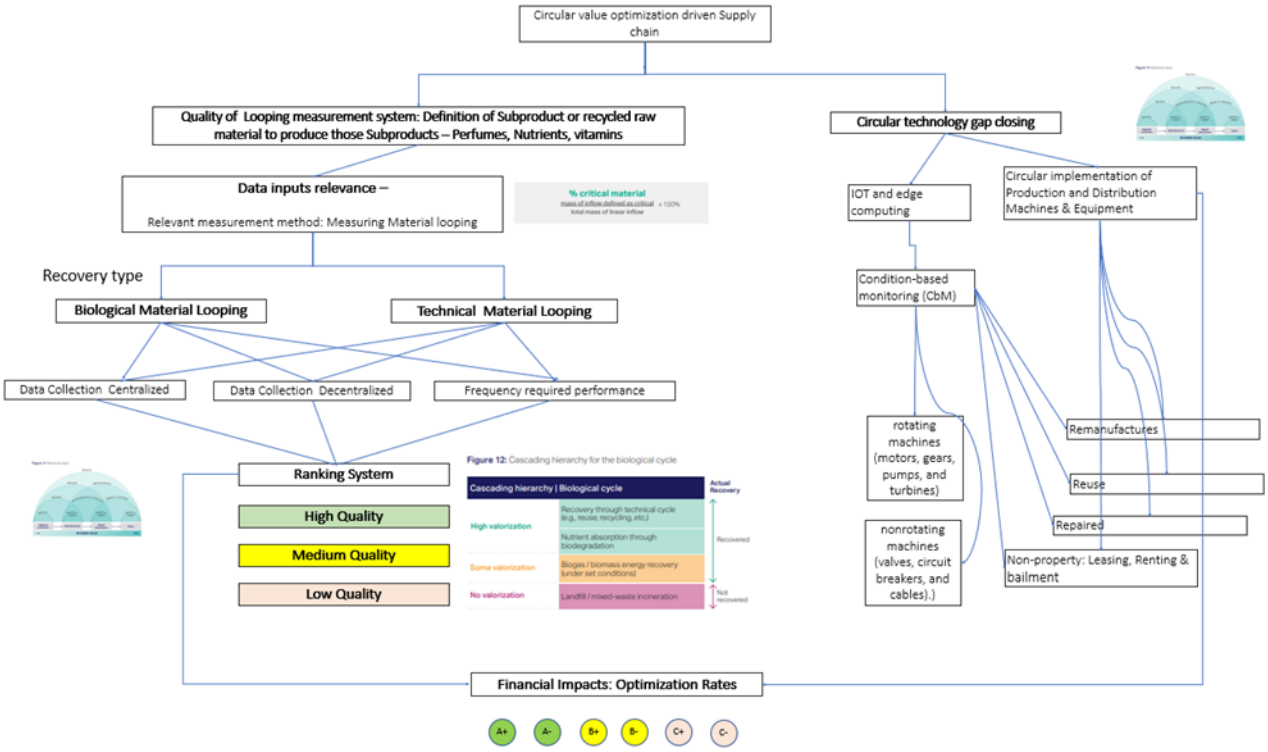

Figure 15: Benchmark system to qualify supply chain performance under circularity

Step by Step Benchmarking System:

1. We begin upon the concept of integration “Circular value optimization driven supply chain”. With this concept, we seek to know the percentage of optimization both for the procurement of recycled raw material, the processing and marketing of by-products. This aspect can be measured in terms of digitization and monitoring of operations, whether by focusing on performance or condition monitoring. Complementary to this, optimization focuses on the adoption of technologies under the principles of remanufacturing and reuse, proposed by the circular economy.
2. On the left side of the benchmarking system, we define the quality level of the close looping processes, based on the measurement of these processes and determine the quality of this measurement and data transmission. If the agents carry out optimization processes and manage to measure these processes and also transmit them to the chain, the production conditions and acceptability of the by-products will improve.
3. On the right side of the bechmarking system, we focus on observing whether the technologies to be adopted carry out digital data collection and develop transmission tools and protocols. In Addition to that, we study if those technologies were acquired and implemented in terms of remanufacturing and reuse, again a factor of optimization of the supply chains value.

4. The ranking is comprised under a 6-level qualification scheme, where the following aspects are related:
   - Relation % Critical material
   - Recuperation %
   - Quality
   - Sale
   - Margin behaviour
   - Value Creation
   - Measuring
   - Integration
   - BPOEs Compliance

This benchmarking system will facilitate the definition levels of the value optimizations and **criteria for choosing technologies that foster sustainability and circularity** in terms of:

1. Technologies and technical processes to obtain recycled raw materials,
2. Commercialization regarding quality aspect depending on the use of technologies,
3. Integrated measurement tools to track quality and enhance supply chain integration
4. Investments hedges in frames of circularity (BPOEs) and high compliance with regulation and industrials standards.

Under these above-described criteria, it will be estimated if a certain supply chain performance has a high compliance or not, and classify them in regard to their optimization rates under the approaches of value losing, retention and creation.

We rank the chains according to 6 rates as follows:

Table 2: Measuring items Benchmark system

Rates	Relation % Critical material	Recuperation %	Quality	Sale	Margin behaviour	Value Creation	Measuring	Integration	BPOEs Compliance
A+	80,00%	80,00%	High	constantly	exponentially	Create	Optimal	High	High
A-	20,00%	75,00%	High	constantly	gradually	Create	Optimal	Middle	High
B+	60,00%	58,00%	Middle	constantly	gradually	Maintain	Middle	Optimal	Optimal
B-	56,00%	49,00%	Middle	With difficulties	Minimal	Maintain	Middle	Middle	Optimal
C+	12,00%	45,00%	Low	sporadically	No impact	No Value	Middle	Middle	Low
C-	89,00%	20,00%	Low	Not action	No impact	Lose Value	Low	Low	Middle

A+: Supply Chains that operate in high rate of value optimization

- Gain % from critical materials: The supply chains obtain a high quality of recycled raw materials and sell constantly high-quality by-products. Therefore, they increase their margin exponentially and create value.
- Measuring (relevant Data and Condition monitoring) performances very well and provides agility, transparent and supply chain integration.
- Closing technologies gaps with high successful circular BPOEs runs under high compliance of regulations and industrial standards.

A-: Supply Chains that operate in high rate of value optimization but show some barriers or rejection aspects

- Gain % from critical materials: They obtain a high quality of recycled raw materials and sell constantly high-quality by-products. Therefore, they increase their margin gradually retain value.
- Measuring (relevant Data and NOT Condition monitoring) performances ok and provides agility, transparent and Supply chain Integration.
- Closing technologies gaps with high successful Circular BPOEs runs under high compliance of regulations and industrial standards.

B+: Supply Chains that operate in an acceptable rate of value optimization

- Gain % from critical materials: they obtain an acceptable quality of recycled raw materials and sell constantly high-quality by product and therefore they increase minimal their margin. Maintain value.
- Measuring (NOT relevant Data and NOT Condition monitoring) is just important and provides some kind of agility, transparent and Supply chain Integration.
- Closing technologies gaps with high successful Circular BPOEs runs under accepted compliance of regulations and industrial standards.

B-: Supply Chains that operate in an acceptable of value optimization

- Gain % from critical materials: They obtain an acceptable quality of recycled raw materials, sell with difficulties by-product and shows a low pace increase of their margin. Maintain value.
- Measuring (NOT relevant Data and NOT Condition monitoring) is not important and provide low agility, transparent but not Supply chain Integration.
- Closing technologies gaps with Circular BPOEs is not a constancy and shows low compliance of regulations and industrial standards.

C+: Supply Chains that operate in a low rate of value optimization

- Gain % from critical materials: They obtain a low quality of recycled raw materials and sell sporadically by-product and increase minimal their margin. No value.
- Measuring (NOT relevant Data and NOT Condition monitoring) is not a performance at all and they experience low agility, low transparent and any kind of Supply chain Integration.
- Closing technologies gaps with Circular BPOEs is not considered.

C-: Supply Chains that operate in low rate of value optimization

- Gain % from critical materials: They don't even consider a recycled raw materials process and not sell any by-product and therefore the impact negatively their margin. Lose value.
- Measuring (NOT relevant Data and NOT Condition monitoring) is not a performance and they experience any kind of agility, any kind of transparency and any kind of Supply chain Integration.
- Closing technologies gaps with Circular BPOEs is not considered.

6 Long-term Competitive Advantage

To conclude the CTRM schematic analysis, we will focus on the long-term competitive advantages, which should be reached if the entire configuration of circular driven value optimization supply chains is successful. In parallel to this, we will point out the gaps that must be closed to reach this competitive advantage. The general objectives of a technology roadmap are aimed at generating a bridge between technology adoption and strategic planning. In this context, future investment will be clarified and supported to attain the exposed business strategy. The main result after defining the investment parameters is the creation or reinforcement of the long-term competitive advantages.

In this stage, we will define the frames in terms of scenarios for the long-term competitive advantages in a close relationship to the entire analysis that has been already carried out.

Figure 16: Long-term Competitive Advantage (LTCA)

6.1 High circular economy compliance levels (LTCA)

The integrated countries and their supply chains will increase their level of sustainability and Circular Economy acceptance. They will be recognized under the successfulness of their process to improve eco-efficiency, sustainable value creation and the enhancement of trust as a consequence of these high compliance levels. The neighbour countries will want to be part of this alternative and other supply chains might be interested in deploying such collaborative and value-driven operations.

6.2 Network of collab tech-providers (LTCA)

Technology providers will apply direct investment to establish core facilities plants and improve remanufacturing and reverse logistics by reducing operational cost from warranties fulfilments. Collaboration will be a win-win standard process as a reason of the consolidation of sustainable vendors, who find attractiveness in those territories (smoothly delivering spare-part and engaging end-custom around efficient take-back and benefit systems). This will drastically reduce their production and logistics cost and expand their markets.

6.3 Boosting local tech capabilities (LTCA)

The four pilot countries, including France and Germany will boost the competences and capabilities of their technicians and operators. They will become experts in IoT Measuring, not just in their countries but also internationally. They will reach a status of circular engineers in an innovative environment, where this competence will be highly sought-after in the future and avoid unemployment, when cybernetic takes place in the production plants.

With these last observations we sketch an integral CTRM, which will be a major tool to research the local production conditions and collect the right data to be introduced into the ADSS and obtain the best scenarios of technology and innovation adoptions for a certain supply chain.

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