Circular TwAIn

AI Platform for Integrated Sustainable and Circular Manufacturing

Deliverable

D2.3 Digital Transformation Pathways assessment and benchmarking

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Definitions and acronyms

6Ps	*6Ps migration model for Digital Transformation in SMEs*
AAS	*Asset Administration Shell*
AI	*Artificial Intelligence*
ATB	*Actual TO-BE*
BM	*Business Model*
C.E.	*Circular Economy*
CA	*Consortium Agreement*
CE6Ps	*6Ps Migration Model for a transformation into a Circular Economy SME*
CT	*Circular TwAIn*
CTwAIn	*Circular TwAIn*
D&E	*Design & Engineering*
DoA	*Description of Action*
DPP	*Digital Product Passport*
DS	*Data Space*
DT	*Digital Twin*
EC	*European Commission*
EL	*Ethical and Legal*
EOL	*End-of-Life*
EPIA	*Ethics Impact Assessment*
EPR	*Extended Producer Responsibility*
ETB	*Expected TO-BE*
EU	*European Union*
IDP	*Industrial Data Platform*
LCA	*Lifecycle Assessment*
LCC	*Life Cycle Costing*
Mx	*Month x*
PaaS	*Product-as-a-Service*
PLM	*Product Lifecycle Management*
PQM	*Production Quality Management*
PS	*Product-Service*
PSS	*Product-Service System*
R&I	*Research and Innovation*
SBU	*Strategic Business Unit*
SC	*Supply Chain*
THB	*Trial Handbook*
TechHB	*Technical Hand-Book*
V&V	*Verification & Validation*
WP	*Work Package*

Disclaimer

Executive Summary

The purpose of this deliverable is to report about the activities performed in the frame of **T2.4 – Socio-technological-business-ethical continuous assessment and 6Ps Transformation**.

T2.4 completes a pathway in WP2 (User Scenarios, Requirements and socio-economic Assessment), that encompasses a lifecycle requirements management method for collecting and harmonizing scenarios, needs and requirements from the industrial pilots.
As provided by the DoA, the purpose of this task is:

- to define roles, responsibilities and procedures for assessing the socio-economic and ethical impact of the enterprises involved in the pilots;
- to provide a system of technical indicators (referring to the product, the processes in the production area and the technological platform supporting vertical and horizontal integration) and of socio-business indicators (people-staff, collaborations with external entities, wide-ranging performance indicators), to measure, assess and evaluate the impacts of the pilots on the respective organizations.

The DoA provides also that such system of indicators has to be derived from the *6Ps migration model for Digital Transformation in SMEs*, an assessment model developed by POLIMI.
There are a considerable number of advantages in choosing such an evaluation system:

- a broad and comprehensive system of indicators, not limited to purely technical and economic aspects;
- uniform criteria in the evaluation of the experiments;
- the tool not only takes a snapshot of the organization's current level with respect to all dimensions examined ("AS-IS"), but also requires identifying the levels of evolution the organization aims to achieve after the experiment ("TO-BE");
- the representation of the results in form of radar charts helps understand the level of internal consistency of the experiment, and offers an intuitive and immediate view of the digital transformation pathways that the organization will be following;
- the systematic approach of this assessment system and the experiences developed in its application can be easily exported to other projects, maximizing the effect of the lessons learnt.

Thus, the activity of T2.4 is planned to take place in two parts:

- the first (M7-M18) involves the development of the assessment and benchmarking tool (adapting the *6Ps migration model for Digital Transformation in SMEs* to a version tailored to Circular Economy) and its application to the pilot cases in their initial phase;
- the second iteration (M22-M36) will take place, instead, towards the end of the project, when the pilots are in their final phase, thus measuring the actual maturity levels achieved by the respective organisations as a result of the pilots.

In this deliverable, since the new assessment tool was derived from the *6Ps migration model for Digital Transformation*, we have devoted Chapter 2 to illustrating the original tool, for the sake of completeness.

In Chapter 3 we describe the new assessment model, result of the first part of the task; the new model has been named "*6Ps Migration Model for a transformation into a Circular*

Economy SME".

In the first part of Ch.3, §3.1, the process that led to the development of the tool is explained. The work has been carried out in a collaborative environment, which proved to be particularly useful since it involved Circular Economy experts in the construction of the survey. This process started in June 2023 and continued until early January 2024; during these months, several calls were organised with the heads of the BATTERY, WEEE and PETRO pilots as well as with experts in assessment models and legal subjects, accompanied by forms to help fine-tune the topics, the questions and the answers. A preliminary desk study was initially carried out to identify the typical themes of the Circular Economy, which was then submitted to the experts to identify the most relevant topics for the construction of the tool.
To give an idea of the quantity and quality of the work carried out, in §3.2 we report a list of the topics we examined in the desk work related to the Circular Economy.

The new tool *6Ps Migration Model for a transformation into a Circular Economy SME* (hereinafter *CE6Ps*) is presented in detail in §§3.3, 3.4 and 3.5.
These are the dimensions of analysis (questions) of the *CE6Ps*:

PRODUCT
Product Design and Engineering
Raw materials
End of Life
Product Lifecycle Management and Digital Product Passport
New Business Models enabled by the Circular Economy
Use of data to enable new Business Models

PROCESS
Design and Engineering
Management of Production and End-of-Life Re-Processing
Quality Management
After-Sales Services
Reverse Logistics Management
Supply Chain Management

PLATFORM
Digital Product Passport
Digital Twin
Asset Administration Shell
Data Spaces
Industrial Data Platform
Data Analytics

PEOPLE
C.E. Strategy
C.E. Culture and Organization
C.E. Implementation
Staff and Expertise

Skills
C.E. Ethics

PARTNERSHIP
Research & Innovation
Training & Education
IT Solution Providers
Suppliers
Customers
Industrial Agreements

PERFORMANCE
Operational/ Technical
Economic
Environmental
Social
Product-Service Lifecycle
Supply Chain

§3.3 illustrates in detail the topics handled in the answers to each question.
In ANNEX 1 – "Circular Economy 6Ps" questionnaire, you may find the entire questionnaire.

§3.4 explains the CE6Ps application methodology, based on five main steps (similarly to the traditional 6Ps):

The assessment takes place online and is recorded on a Qualtrics platform.

§3.5 explains CE6Ps outcome, that is in form of radar charts, same as in the original 6Ps.

In Chapter 4 we provide a summary of Circular TwAIn pilots and use cases, who took part in the compilation; such descriptions can be found in much more detail in other deliverables, but we deemed it useful to have a recall here to provide a complete frame to the reader.

The assessment was conducted among the three pilots, considering the distribution of use cases within the pilots.

In Chapter 5 we describe the conduct of the assessment. Our approach was to ask the consortium members involved in the pilots to make a single compilation that included all the use cases for which they were responsible. Responses were to be given by reasoning about the impact the set of use cases had on their respective organizations.

The results of the survey are presented in Chapter 6.

In § 6.1 we begin with an analysis of the aggregate results of the 4 compilations, both in overall view and in detail by pillar. This type of analysis is useful because it allows us to understand the impact of the Circular TwAIn Project on its members in general, and which pillars and dimensions are most impacted by the Project.

The main excerpts from the analysis are:

- the Circular TwAIn Project impacts, as predictable, all the pillars and dimensions examined by this assessment;
- although Circular TwAIn is a Project with important technical content, respondents predict that the socio-business pillars will have slightly higher TO-BE values than the technical pillars; this is mainly due to the higher AS-IS (starting) values in the socio-business pillars;
- however, the gaps expected to be filled in the three technical pillars are greater than the gaps expected to be filled in the socio-business pillars, meaning that the largest progress will take place in the technical pillars;
- this ends in Expected TO-BE values in the technical pillars almost equal to the ones of the socio-business pillars.

Our explanation is that the companies who took part in Circular TwAIn Project did so with the aim of developing products, processes and platforms in circular function. These companies already have a predisposition toward the circular economy (as we can understand from the high AS-IS scores of PEOPLE, PARTNERSHIP and PERFORMANCE). Their purpose is to leverage on the Circular TwAIn Project to boost also the three technical pillars (PRODUCT, PROCESS; PLATFORM), as it is demonstrated from the larger gaps filled in these three pillars.
§6.1 provides detailed explanations pillar by pillar.

After examining the overall impact of the Circular TwAIn Project on the pilots through the aggregate view of §6.1, we turn to the analysis of the responses of individual use cases in §6.2.
As mentioned, the 4 pilots respondent to the compilation are: REVERTIA (WEEE), SOCAR (Petro), COBAT (Battery), RAEEMAN (Battery).
In this section, we describe the peculiarities of each. In extreme synthesis (refer to §6.2 for all details):

- in Cobat (Battery) we observe a pattern similar to the aggregate pattern
- in Raeeman (Battery) we note some similarities (in the socio-business pillars) and some differences (in the technical pillars) with the general pattern
- in Revertia (WEEE) we observe a slightly different pattern from those in the Battery, and also from the overall pattern; in fact, this pilot is presented with the goal of achieving general improvement in all areas examined, rather than focusing effort on only a few
- in Socar (Petro) only part of the questions were answered, as some of them were deemed not suitable for an Oil & Gas company; the pattern of the answers is peculiar.

Finally, in Chapter 7 we draw lessons learnt and conclusions.
The lessons learnt invest multiple aspects of this work: there is a level of learning for the POLIMI interviewers themselves; there is a level of learning for the interviewees; there is a broader level of lessons learnt, thanks to the deeper awareness coming from dissemination; and, finally, there is an even broader level of lessons learnt, that refers to the possibility to

transfer this experience into other European projects.
Task 2.4 of WP2 states that two iterations will take place, one at M18, where responses are given according to expectations from the pilot, and a second one at M36, at the end of the project, when actual results of the experiments will be available. The second iteration of the experiment will be run after the experiments are completed, so as to compare the expected / planned outcome with the actual ones.
This is due in month M36 and will be the subject of deliverable D2.6.

1 Introduction

1.1 Scope

The purpose of this deliverable is to report about the activities performed in the frame of **T2.4 – Socio-technological-business-ethical continuous assessment and 6Ps Transformation**.

T2.4 completes a pathway in WP2 (User Scenarios, Requirements and socio-economic Assessment), that encompasses a lifecycle requirements management method for collecting and harmonizing scenarios, needs and requirements from the industrial pilots.

WP2 objectives are:

- to define a methodology for engineering requirements to be adopted along the whole lifetime of the project (T2.1)
- to analyse industrial pilots' scenarios and derive requirements for the Methodological Framework (WP3) the Data Space for Circularity (WP4) and for the AI implementation toolkit (WP5) (T2.2)
- to specify the ecosystem of AI enhanced Digital Twins including human factors and collaboration (T2.3)
- to define performance indicators at the different levels and to put in place the proper mechanisms and procedures to constantly measure and assess them including those related to trust and ethics (T2.4)

With reference to the last task, T2.4, the DoA provides that "The 6Ps model (AI REGIO) for Digital Transformation assessment and benchmark will be extended and tailored for the Circular Economy application domains. In particular, the model will establish the impact of AI technologies on Products, Processes, Platforms, People, Partnerships, Performance in a Circular value chain."

The purpose of this task is:

- to define roles, responsibilities and procedures for assessing the socio-economic and ethical impact of the enterprises involved in the pilots;
- to provide a system of technical indicators (referring to the product, the processes in the production area and the technological platform supporting vertical and horizontal integration) and of socio-business indicators (people-staff, collaborations with external entities, wide-ranging performance indicators), to measure, assess and evaluate the impacts of the pilots on the respective organizations.

Such system of indicators will be derived from the *6Ps migration model for Digital Transformation in SMEs*, an assessment model developed by POLIMI. There are a considerable number of advantages in choosing such an evaluation system:

- a broad and comprehensive system of indicators, not limited to purely technical and economic aspects; although these are, obviously, fundamental to assess the impact of an experiment on an organization, T2.4 specifically has, among its objectives, to extend the assessment to aspects related to personnel, external collaborations and social-environmental impact, which is fully met by the adopted tool;
- uniform criteria in the evaluation of the experiments; the 6Ps not only provides objective measurement tools for the experiments, but also makes it possible to compare the results of experiments with each other, according to different aggregation criteria; that

is, it provides experiment leaders with a common language on which to compare, fostering collaboration and knowledge;
- the tool not only takes a snapshot of the organization's current level with respect to all dimensions examined ("AS-IS"), but also requires identifying the levels of evolution the organization aims to achieve after the experiment ("TO-BE");
- the representation of the results in form of radar charts, as comprehensive views of all the areas examined (the 6 "pillars"), helps understand the level of internal consistency of the experiment, and offers an intuitive and immediate view of the digital transformation pathways that the organization will be following;
- the systematic approach of this assessment system and the experiences developed in its application can be easily exported to other projects, maximizing the effect of the lessons learnt.

Task T2.4 is planned to take place in two parts:

- the first (M7-M18) involves the development of an assessment and benchmarking tool, and its application to the pilot cases in their initial phase;

- the second iteration (M22-M36) will take place, instead, towards the end of the project, when the pilots are in their final phase, thus measuring the actual maturity levels achieved by the respective organisations as a result of the pilots.

The first part is therefore more substantial and laborious, as it also includes the setting and fine-tuning of the new assessment and benchmarking tool.
The second part will, on the other hand, be quicker, but when the results are processed, it will provide more information because it will also include a comparison with the expected results expressed in the first iteration of the assessment.

Purpose of T2.4 is also to factorise such an assessment in WP2, so that lessons learnt could be shared and recommendations could be issued for the consortium and, also, beyond the project.

1.2 Structure of the deliverable

Since the new assessment tool was derived from the *6Ps migration model for Digital Transformation*, we have devoted **Chapter 2** to illustrating this tool, for the sake of completeness. Chapter 2 illustrates the 6Ps migration model starting with the presentation of some digital maturity tools developed by POLIMI (Test Industry 4.0 and Dreamy), in order to provide the reader with a broader context. The 6Ps migration model is then described in detail: the 6 pillars, the digital transformation path, the outcomes.

Chapter 3 presents the new evaluation and benchmarking tool, called "***6Ps Migration Model for a transformation into a Circular Economy SME*** ".
In the first part, §3.1, the process that led to the development of the tool is explained.
In §3.2, they are outlined the typical topics of the Circular Economy that were examined for the purposes of the assessment model.
In §§3.3, 3.4 and 3.5, the tool and its operation are described.

The complete tool, with all its questions and answers, can then be found in ANNEX 1 – "Circular Economy 6Ps" questionnaire.

Chapter 4 (Circular TwAIn Pilots and Use Cases) carries short descriptions of the four CTwAIn pilots to which the assessment was applied (Battery-Cobat, Battery-Raeeman, WEEE-Revertia, Petro-Socar); although there are other deliverables in which the pilots have been described in great detail, we found it useful to summarize them in Chapter 4, considering that the 6Ps model deals, in this case, with the pilots, the benefits they can bring to the respective organizations, the methods for measuring those benefits (of which 6Ps is one), and the experience gained, so that lessons learnt can be shared and recommendations can be made for the consortium.

Chapter 5 (Conduct of the assessment) is dedicated to explain the methodology followed by POLIMI in the delivery of the assessment: meetings, participants, project managers, online compilation, processing of results, reports.

In **Chapter 6** the results of the assessments are presented.
In the first part (6.1), the results of the assessment on the aggregate of the 3 pilots are presented; the aim is to give an overview of the impact of the Circular TwAIn Project on the consortium. This analysis is conducted on a pillar-by-pillar and dimension-by-dimension basis, and allows to understand the general pattern.
In the second part (6.2), we shall see how the Circular TwAIn Project impacted on the individual pilots, according to the answers given by the compilers. In this analysis, similarities and differences will emerge.

Chapter 7 ends D2.3 with final considerations about the results and benefits achieved, both by the individual experiments and at the overall project level, with a description of the next steps and with some indications of the results we can expect in the second iteration.

2 The original 6Ps Migration Model for Digital Transformation

2.1 Digital Maturity assessment tools of Politecnico di Milano

Digital Maturity is about the capacity of an enterprise to meet the challenges of the digital world by adopting and exploiting those technologies which are highly relevant for its competitiveness. Digital Maturity must be considered as an evolutionary state, that requires continuous adaptation to the changing digital environment. Politecnico di Milano has developed several digital transformation assessment models, to assess the digital maturity of organizations and to suggest roadmaps and journeys for the implementation of digital transformations.

Among POLIMI's digital transformation tools, we can mention:

- the Dreamy Assessment tool
- the Test Industry 4.0
- the 6Ps Migration Model for the Digital Transformation in the SMEs

2.1.1 The Dreamy assessment tool

Dreamy 4.0 methodology is an in-depth analysis tool, consisting of more than 200 questions, aimed at measuring the level of **digital maturity** of a manufacturing company, focusing on six process areas typical of Industry 4.0:

- **Design & Engineering**
- **Production**
- **Quality**
- **Maintenance**
- **Logistics**
- **Supply Chain**

Figure 1 – The DREAMY processes

These process areas are analyzed in four dimensions of analysis: **Organization**, **Execution**, **Monitoring & Control**, **Technology**.

Figure 2 – The DREAMY four dimensions of evaluation

A digital maturity value is calculated for each combination Process area / Dimension of analysis, according to a **Digital Maturity Scale** structured on five levels of maturity:

Maturity Level 1: Initial. The process is poorly controlled or not controlled at all.
Maturity Level 2: Managed. The process is partially planned and implemented. The process is poorly/little controlled.
Maturity Level 3: Defined. The process is defined with the planning and the implementation of good practices and management procedures.
Maturity Level 4: Integrated and interoperable. The process is built on information exchange, integration, and interoperability across applications; and it is fully planned and implemented.
Maturity Level 5: Digitally oriented. The process is digitally-oriented and based on a solid technology infrastructure and on a high potential growth organization, which supports the decision making.

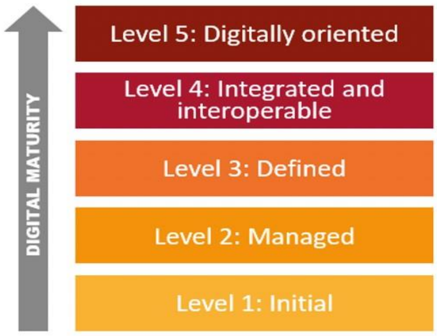

Figure 3 – The DREAMY four dimensions of evaluation

Results are provided:

- in the form of radar charts, providing a perspective of the dimensions of analysis (Organization, Execution, Monitoring and Technology) and of the digital maturity by process areas and their functions;
- joint to an analysis of strengths and weaknesses, and suggestion of improvement actions.

Figure 4 – The DREAMY scale with the five levels of maturity

As an in-depth tool, Dreamy is performed on premise; the whole questionnaire normally takes two days of interviews, with managers of the company from the six mentioned processing areas.

2.1.2 Test Industry 4.0

The **Test Industry 4.0** in an online questionnaire of about 130 questions, that has been developed by Politecnico di Milano with the aim of assessing the digital maturity of a company; in part, it is a derivation of Dreamy.

The tool analyses 10 different company's processes and functions:

- 6 of which are a derivation of Dreamy: Design & Engineering, Production, Maintenance, Quality, Logistics, Supply chain;
- 4 have been added to achieve a complete perspective of the company: Strategy, Marketing & Sales, Smart Products and Human Resources.

Figure 5 – The ten areas of Test Industry 4.0

The dimension of analysis and the evaluation scale are the same as in the Dreamy: **Organization**, **Execution**, **Monitoring**, **Technology**.

The ranking scale is also of the same type as the Dreamy Test, and involves assigning 5 levels of increasing digital maturity.

Results are provided in the form of radar charts, providing a perspective of the dimensions of analysis (Organization, Execution, Monitoring and Technology) and of the digital maturity by process area or function.

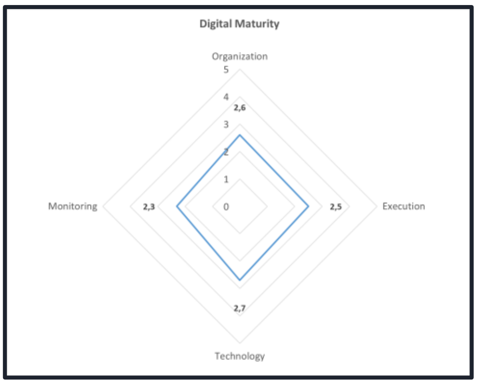

Figure 6 – Test Industry 4.0 output: Overall Digital Maturity, by dimension

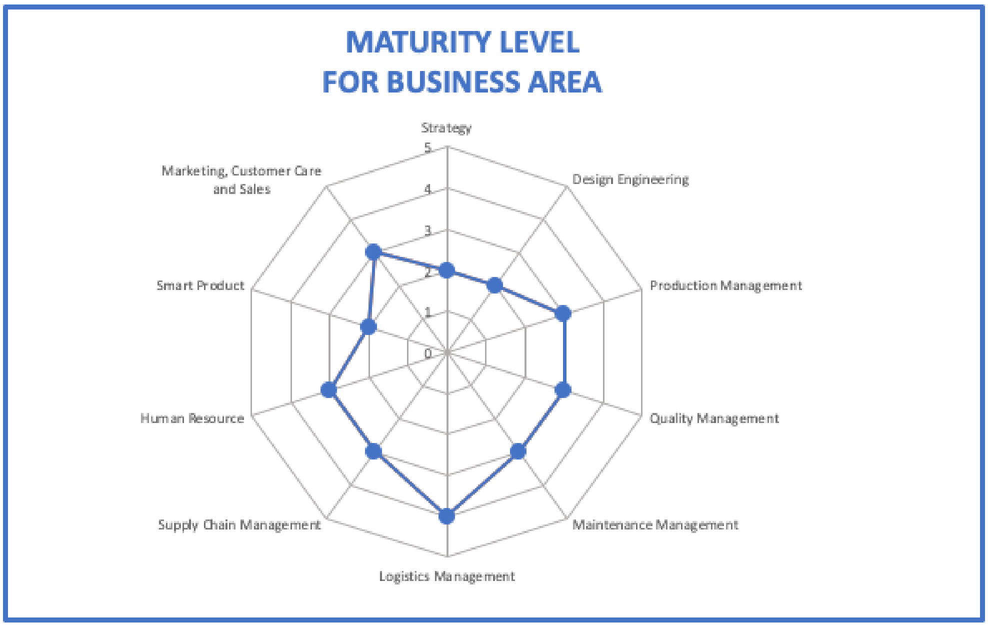

Figure 7 – Test Industry 4.0 output: Overall Digital Maturity, by area

Additional levels of detail are possible, indicating the level of response of each individual question for each process area or function:

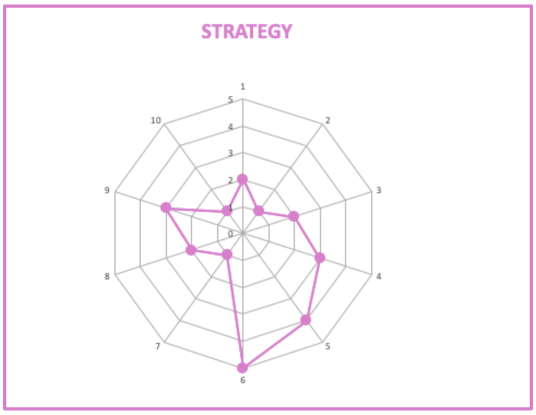

Figure 8 – Test Industry 4.0 output: Digital Maturity of the Strategy area

The online survey is publicly available at https://www.testindustria4-0.com/.

2.2 6Ps Migration Model for Digital Transformation in SMEs

The assessment model that we are going to use in the Circular TwAIn Project derives from the *6Ps migration model for Digital Transformation in SMEs*, also developed by the POLIMI (like the tools described above), in this case within the AI REGIO Project, where it was successfully applied to the analysis of 17 internal project use cases plus another 17 use cases from Open Calls.

In this section we will describe such tool in its original form (geared towards measuring the level of digitisation of organisations, particularly manufacturing SMEs), while in Chapter 3 we will describe how it was modified to apply to Circular Economy concepts.

The *6Ps migration model for Digital Transformation in SMEs* is a tool to support

manufacturing companies to assess their current and expected level of digitization, along 6 dimensions, and to track a Digital Transformation roadmap.
Unlike Test Industry 4.0 and Dreamy, that can be considered as strategical tools, 6Ps has a more tactical approach, meaning that the company already has in mind its gaps, but it needs an effective set of actions to fill them. This set of actions is the Digital Transformation roadmap.

When we say that the company has already in mind its gaps, we mean that, either:

- the company has a project to improve some aspects of its approach to digitization; in this case, the roadmap to the implementation of digital solutions is implicitly defined by the project, and the 6Ps helps measure where progresses take place and how large they are;

or

- the company has identified some digitization gaps and wants to fill them: in this case, 6Ps provides a support to focus on the potential areas of improvement, and as an "inspirational" tool, suggesting concrete ideas of actions to implement digital solutions that may add to the company's ideas.

2.2.1 The 6 Pillars

The 6Ps methodology is a tool conceived to support enterprises along their digital transformation journey, by providing a complete analysis of the main six pillars that characterise the production process. It is based on the assumption that, to succeed in a digital transformation process, it is important to boost not only the technical dimensions, but also the so called "socio-business" dimensions.
The six Pillars of analysis (from which, the name "6Ps") are: Product, Process, Platform, People, Partnership and Performance, grouped in three "technical" and three "socio-business" pillars.

Figure 9 – The 6 PILLARS

Each pillar is composed of at least six different dimensions of analysis, typical of Industry 4.0. Each analysis dimension is broken down into five sequential development stages, from the least to the most advanced one with respect to Industry 4.0 adoption.

The PRODUCT pillar

6Ps' **Product pillar** has the objective of evaluating in a quantified way to which extent the manufacturing company is digitally mature in terms of Product or Product-Service System that it offers to the market. This is the first dimension analysed, as the product constitutes the direct link that manufacturing companies have with their customers, thus significantly affecting the overall performances of the firm.
The six different fields of analysis are related to: **Sensors and actuators** (to understand how the product is equipped); **Communication and Connectivity** (to measure how the product is able to communicate with external devices); **Storage and Exchange of information** (to measure if the product is able to storage data); **Monitoring** (to assess if the product is able to self-monitor its status); **Product-related IT services** (to measure the level of service related to the product); **Business Models enable by the product** (to measures how the digital maturity of the product impacts on the company's business model).

The PROCESS pillar

6Ps' **Process pillar** has the main objective of assessing the level of digital maturity in the production processes of a manufacturing company.
The six analysis fields are: **Design & Engineering** (to evaluate how these processes are enabled by digital technologies); **Production Management**; **Quality Management** (how quality is managed to avoid quality issues); **Maintenance Management** (to measure how much digital technologies characterize maintenance activities); **Logistics Management** (to assess the digital maturity level of the logistics processes); **Supply Chain Management** (to evaluate to which extent digital technologies are exploited in this field).

The PLATFORM pillar

The **Platform pillar** suggests migration pathways towards Digital Platforms supporting vertical integration (from the shop floor to the enterprise level), and horizontal integration along the value chain and end-to-end engineering.
In this respect, six technological fields of analysis are considered: **CPS and embedded systems** (to measure how much the firm is able to use the data collected from the field); **Industrial Internet of Things** (ability in using and integrate IoT devices); **Industrial Internet** (how factory assets are linked to the common internet platform); **Industrial analytics** (to evaluate the capacity of the company in exploiting analytics); **Vertical interoperability of data and events** and **Horizontal interoperability of data and services** (to measure the capabilities of manufacturing companies in collecting, manipulate and manage data that are necessarily heterogenous in an integrated way).

The PEOPLE pillar

6Ps' **People pillar** aims at assessing the skills owned or to be owned among staff.
A digital transformation process cannot ignore the involvement of staff. Actually, staff, with their expertise, are the real drivers of digital transformation. When operating a digital transformation process, staff skills, training and involvement are the real heart of the change. For this reason, to this pillar they are dedicated 12 questions, instead of 6.
Because of the high variance in the roles operating in the sector, this pillar has been at first divided into 5 macro-professions, namely: **Blue Collars, Operators I4.0, Digital Transformation Professional, I4.0 Professional, Managers & C-Levels** and then six

fields of interest have been identified as well.
These 6 fields of interest are: **Industry 4.0 Strategy** (awareness about industry 4.0), **Smart Operations**, **Smart Supply Chain**, **Smart Product-Service Engineering**, **Industry 4.0 Infrastructure** and **Big Data** (to assess the level of skills in the field of Big Data).

The PARTNERSHIP pillar

The **Partnership pillar** relates to the identification of the partners needed for digitalization and to achieve the desired business goals. It describes workflows whose purpose is to support the transition towards more collaborative relationships with key stakeholders in the digital ecosystem, in order to create strong and collaborative partnerships.
Accordingly, potential partners included in the dimensions are: **DIHs**, **Research and Innovation, Education and Training Providers, IT Solution Providers**, **Suppliers and Customers**.

The PERFORMANCE pillar

6Ps' **Performance pillar** aims at investigating the way the indicators of the manufacturing companies are defined, measured and monitored. Unlike it may seem at a first glance, this pillar doesn't assess if the value of an indicator will improve, but if the way the indicator is measured is expected to become more accurate.
The dimension is divided into 6 areas, namely: **Operational/Technical** (to monitor the performances of machines and production activities, such as OEE); **Economics** (KPIs focused on economic and financial results, such as ROI); **Environmental** and **Social** (to measure these performances and covering all the aspects of the triple bottom line); **Product-Service Lifecycle** (to assess how, to which extent and according to which criteria the Product-Service System is assessed); **Supply Chain** (modalities through which the company measures the overall performances of their entire Supply Chain).

2.2.2 Maturity Scale

The 6Ps Maturity Scale is structured on five levels, as follows:

Maturity Level 1: Initial
The dimension is poorly digitized or not digitized at all. Processes are little or not controlled, and managed reactively.

Maturity Level 2: Managed
Some aspects of the organization are digitized and controlled, such as a pilot or an ongoing digitization project. Processes are partially controlled and partially managed by experience.

Maturity Level 3: Defined
Digitized activities are defined and implemented in the organization. Processes are planned and apply good practices and management procedures.

Maturity Level 4: Integrated
Processes are fully planned and implemented, and built on information exchange, integration and interoperability across applications. Presence of best practices and of common and shared standards.

Maturity Level 5: Exploited

The organization has reached a level of full exploitation in that dimension. The process is digitally-oriented and is based on a solid technology infrastructure and on a high potential growth organization, which supports the decision making.

2.2.3 The Digital Transformation Journey

The methodology includes an assessment defined from a tactical perspective (aiming at helping companies to generate strategies for approaching and moving forward Industry 4.0) and it serves as a starting point and a basis for new ideas and roadmaps. It helps the enterprises to highlight the main gaps to be filled with a digital transformation process since it is required to evaluate both the current and the expected level, for each pillar and sub-dimension.

The methodology is based on five main steps:

1. **Set-up of a team bringing together different organizational areas**: the identification of the staff able to detect the main gaps in the several dimensions of the company is fundamental to drive the company toward the digital transformation.
2. **Identification of the AS-IS profile of the manufacturing enterprise**: the manufacturing enterprise's strategy, competitive strengths and weaknesses, etc. must be analysed. Then, its current profile must be mapped into each dimension and development stage of every migration pillar.
3. **Definition of the target TO-BE profile of the manufacturing enterprise**: the future vision and desired profile of the manufacturing enterprise must be defined considering the links to the business and competitive priorities, and thus mapped onto each dimension and development stage of the 6P pillars.
4. **Identification of actions, feasibility and prioritization**: this step is about identifying the actions needed to migrate from the AS-IS to the TO BE and considering the links to the business strategy as well as benefits and costs, risks and dependencies, evaluating to what extent investments are justified and what actions should be prioritized.
5. **Development of the Migration Plan towards Industry 4.0**: finally, the migration plan is developed. To this respect, different approaches can be adopted.

2.2.4 6Ps output

The output of the 6Ps is in form of radar charts, as exemplified in Figure 10.

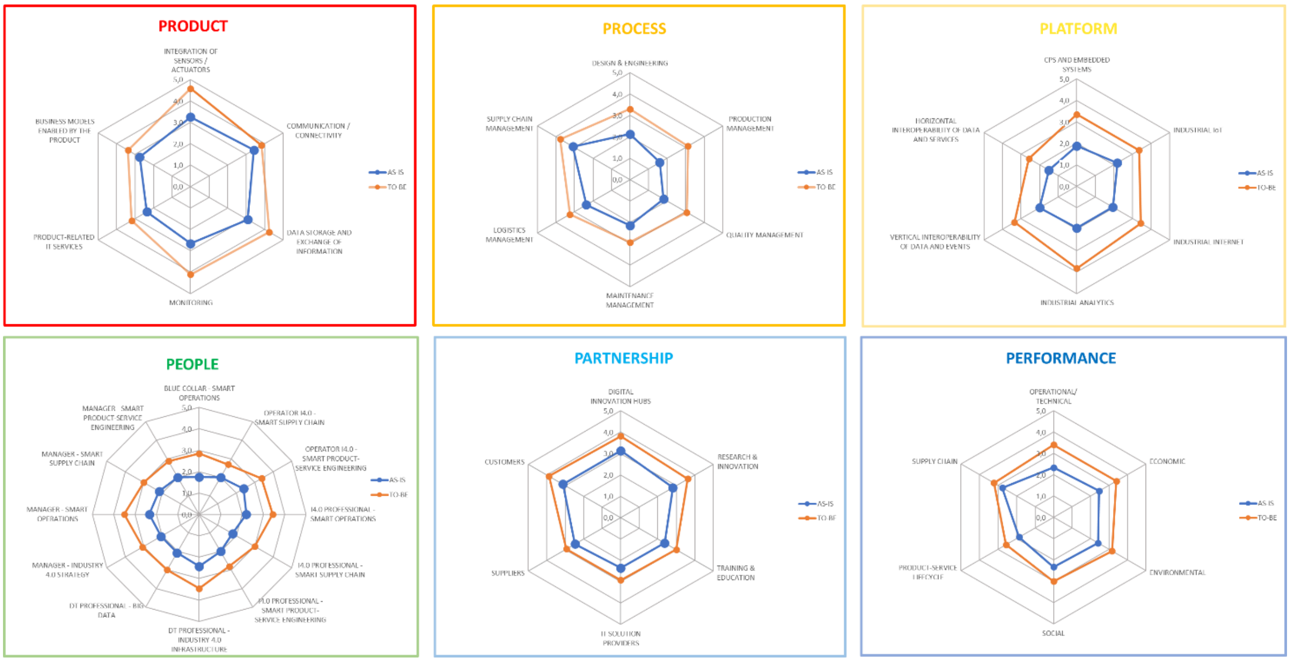

Figure 10 – The 6Ps Output

A radar chart is processed for each Pillar, on which axes there are the dimensions of analysis, each with its AS-IS and TO-BE scores.

We can see that the 6Ps offers a broad and comprehensive system of indicators, not limited to technical and economic aspects alone; the 6Ps extends its arm to aspects related to personnel, external collaborations, and social-environmental impact.

The tool not only takes a snapshot of the organization's current level with respect to all the dimensions examined ("AS-IS"), but also requires identification of the levels of digital evolution the organization intends to achieve after the use case ("TO-BE"). The gaps to be bridged between AS-IS and TO-BE constitute the organization's digital transformation path. This path is immediately apparent through the representation of the results in the form of radar diagrams, which provides an overall view of all the areas examined (the 6 "pillars"), helping understand the level of internal coherence of the strategy, and offering an intuitive and immediate view of the digital transformation paths that the organization will follow.

Thus, the 6Ps can be considered both as an assessment tool (it measures the maturity of the organization in the various dimensions of analysis, AS-IS) and as a tool that suggests concrete ideas and helps the organization focus on its digital transformation path.

3 The "6Ps Migration Model for a transformation into a Circular Economy SME"

In the previous chapter, we described the *6Ps migration model for Digital Transformation in SMEs* in its original version. The tool, which started out as a tool for measuring digitisation in manufacturing SMEs, has had, over the course of the various European projects, different declinations depending on the project in which it was applied; there have been instantiations dedicated to the Process Industry, to AI, to X-AI and to Data/AI (measuring the readiness of SMEs to use artificial intelligence and data), and sector-specific instantiations that consisted of small adaptations of the tool to make it more compliant with investigating companies in the Energy, Agri-food and Health&Care sectors.

In the case of the adaptation of the 6Ps to the Circular Economy, however, our approach was not to adapt the original tool, but rather to remake it from scratch, while respecting the original structure of the 6 pillars, each with 6 questions and 5 levels of answers. In this case, in fact, the objective was not to measure the degree of digitisation of companies (possibly declined in AI or data or adapted to a specific sector), but rather to understand the degree of predisposition of companies towards the Circular Economy. Therefore, a complete review of the tool was necessary.

The criterion followed was to maintain the general structure of the 6Ps, which is divided into the six sections PRODUCT, PROCESS, PLATFORM, PEOPLE, PARTNERSHIP and PERFORMANCE, reformulating in full the six questions contained in each and, of course, their answers.

In the following paragraphs, we will describe in detail how the new 6Ps dedicated to the Circular Economy was built. This new version will be named, in short, "**Circular Economy 6Ps**" or "**CE6Ps**".

3.1 Setting-up the tool

The reformulation of the 6Ps into a Circular Economy version was foreseen in Task 2.4 according to the DoA wording, which reads: "T2.4 (Socio-technological-business-ethical continuous assessment and 6Ps Transformation) will define roles, responsibilities and procedures for assessing the socio-economic and ethical impact of the Enterprises involved in the experiments. The 6Ps model (AI REGIO) for Digital Transformation assessment and benchmark will be extended and tailored for the Circular Economy application domains. In particular, the model will establish the impact of AI technologies on Products, Processes, Platforms, People, Partnerships, Performance in a Circular value chain." The consortium members involved in this task were expected to be, according to the DoA: POLIMI (leader), NISSATECH, SUITE5, NOVA, INTRA, GFT, RECYCLIA, REVERTIA, EAI, TEKNOPAR, COBAT, SOCAR, RAEEMAN and SSF.

The Task therefore involved, in the first instance, the development of a new assessment tool, based on the *6Ps migration model for Digital Transformation in SMEs* developed within the MIDIH and AI REGIO projects and customised on the Circular Economy, and then the application of the same to the pilots of the Circular TwAIn Project.

Regarding the first part - the development of a 6PS customized on Circular Economy - the work has been carried out in a collaborative environment, which proved to be particularly useful as it allowed to involve Circular Economy experts in the construction of the survey. This process started in June 2023 and continued until early January 2024; during these months, several calls were organised with the heads of the BATTERY, WEEE and PETRO pilots as well as with experts in assessment models and legal subjects, accompanied by forms to help fine-tune the topics, the questions and the answers. The calls were attended by the following consortium members: POLIMI (leader), ENG, NISSATECH, SUITE5, NOVA, INTRA, GFT, RECYCICLIA, REVERTIA, EAI, TEKNOPAR, COBAT, SOCAR, RAEEMAN, AIMEN.

The aim of the work was to try to best encompass in the survey questions and answers the typical characteristics of the Circular Economy. To do this, a preliminary desk study was initially carried out to identify the typical themes of the Circular Economy, which was then submitted to the experts to identify the most relevant topics for the construction of the tool.

Compared to the DoA work plan (that provided for the completion of the activity by M18), the timeframe was slightly longer; this was due to the need to develop a comprehensive and convincing tool, with numerous actors involved in its preparation, work that coincided with the deadlines of other projects, which caused some delays. Although the time was, in the end, a little longer than planned, we are confident we have been able to set a useful and convincing tool.

3.2 Circular Economy topics at issue

To give an idea of the quantity and quality of the work carried out, in this section we shall report a list of the topics we examined in the desk work related to the Circular Economy.

DESIGN & ENGINEERING

In a Circular Economy, the design and engineering of a new product should prioritize sustainability, resource efficiency, and the ability to promote a closed-loop system where materials and products are continually reused, refurbished, remanufactured, or recycled. Here are the issues that we examined about the designing and engineering of a new product in a Circular Economy:

- material selection; use of sustainable materials
- durability and longevity
- ease of maintaining, repair and disassembly
- modularity
- recyclability & upcyclability
- reuse & refurbishment
- waste minimization
- energy efficiency, water efficiency
- toxicity, minimal use of hazardous substances
- innovation in material design, eco-design
- reverse logistics and take-back programs
- supply chain sustainability and transparency
- product lifespan, lifecycle thinking, life cycle assessment (LCA)
- Product-as-a-Service (PaaS)
- Digital Twins
- collaboration with stakeholders
- consumer engagement, education and awareness
- circular business models
- regulations and standards

RAW MATERIALS

Here the focus is on closing the loop of product life cycles to ensure maximum value retention of resources and minimum waste. When it comes to raw materials, several issues arise:

- material selection; use of sustainable materials
- scarcity and depletion
- effective collection and sorting systems
- quality control
- waste as a resource
- technological advances
- supply chain integration
- traceability and transparency
- economic implications
- market development and demand creation
- stakeholder collaboration
- extended producer responsibility (EPR)
- regulatory frameworks
- certification and standardization

PRODUCTION PROCESSES, PRODUCT END-OF-LIFE AND PRODUCT RE-PROCESSING

Whereas in the original 6Ps, dedicated to digital transformation, this pillar referred to production management, in this case the question has been transformed into a version that takes into account not only the production process understood as the transformation of virgin raw materials, but also as an opportunity to recycle and reprocess products and materials at the end of their life, in a circular perspective. As a matter of fact, in a Circular Economy, managing the connections among production processes, product end-of-life, and product re-processing is crucial to achieve a closed-loop system where resources are continually reused, refurbished, remanufactured, or recycled. Here are the key concepts that we have examined in this concern:

- product D&E for Circular Economy
- material selection and traceability
- resource recovery and recycling
- repair, re-manufacturing and refurbishment
- upcycling and downcycling
- optimize end-of-life management
- closed-loop recycling
- reverse logistics and take-back programs
- integrate and enhance production and re-processing
- shared facilities
- digital tracking and traceability
- Digital Product Passport
- data analytics and optimization
- transparency & communication
- collaborative supply chain; collaboration with suppliers, partners, and even competitors
- consumer engagement and education
- feedback loops
- innovative circular business models

- standardization and modularity
- regulatory compliance & advocacy

PRODUCTION QUALITY MANAGEMENT

Production Quality Management (PQM) focuses on ensuring that products meet set standards and specifications. When viewed from a Circular Economy perspective, PQM takes on added dimensions, emphasizing not only the traditional aspects of product quality but also the long-term sustainability, recyclability, and reusability of products. Here's what we should investigate about Production Quality Management for its alignment with the principles of the Circular Economy:

- quality control systems
- material selection
- design for longevity
- raw materials certification and standardization
- modular design and standardization
- end-of-life planning
- production process optimization
- supplier management
- feedback loops
- product traceability
- continuous improvement
- consumer engagement

REVERSE LOGISTICS

Reverse logistics plays a crucial role in the Circular Economy by managing the flow of products, materials, and resources back into the value chain after their initial use, thereby enabling a more sustainable and efficient resource management system. In a linear economy, products are typically used and discarded, leading to waste and environmental degradation. Reverse logistics refers to the process of moving goods from their final destination back to the manufacturer or a similar location for the purpose of return, repair, remanufacturing, recycling, or disposal. In the context of the Circular Economy, reverse logistics plays a pivotal role in facilitating the looped life cycle of products and materials, aiming to maximize resource efficiency and reduce waste. Here's the aspects related to reverse logistics that we have considered:

- product returns & refurbishing
- repairs and warranty recovery
- remanufacturing and reprocessing
- recycling and material recovery
- reduction of waste to landfill
- packaging reuse
- inventory management
- supply chain transparency; traceability
- database and monitoring
- data integration and analysis
- advanced automation and routing
- extended producer responsibility (EPR)
- consumer engagement
- economic value creation
- regulatory compliance

SUPPLY CHAIN

The supply chain processes are re-envisioned to prioritize the sustainability and efficient use of resources throughout the product lifecycle. The traditional linear supply chain model — where products are made, used, and then disposed of — transforms into a circular model where waste is minimized, and products and materials are reused, repaired, and recycled to create new value:

- product design and development
- sourcing and procurement
- recycled, reusable or renewable materials
- manufacturing
- distribution and logistics
- end-of-life management
- product returns, repairs, remanufacturing and recycling
- reverse logistics systems
- services to extend product life
- collaboration with suppliers and with recycling facilities
- sales and marketing
- usage and service

AFTER-SALES

In a Circular Economy, providing after-sales services is essential to ensure the longevity and sustainability of products, as well as to monitor their life-cycle. These services aim to promote the principles of reduce, reuse, refurbish, and recycle. Here are some key factors:

- product repair and maintenance
- spare parts availability
- remote troubleshooting, diagnostics & support
- extended warranties
- product refurbishment and remanufacturing
- end-of-life instructions
- take-back & recycling programs
- trade-ins programs
- leasing & renting models, product-as-a-service (PaaS)
- loyalty programs for sustainable behaviour
- collaboration with recycling facilities
- monitoring and data collection
- digital product passports
- transparent communication
- consumer education & training
- feedback systems
- Digital twins
- Digital Product Passport

END-OF-LIFE

"End-of-life" refers to the stage in a product's lifecycle where it has reached the end of its useful life for its original purpose, and it is no longer used or needed by the consumer. At this point, the product can become waste or be discarded. Instead of being treated as waste, products at their end-of-life are considered valuable resources that can be recovered, reused, remanufactured, or recycled to create new products or extend their useful life. The goal is to keep products and materials circulating in a closed-loop system, minimizing the need for virgin resources and reducing the environmental impact associated with resource extraction, manufacturing, and waste disposal. The Circular Economy employs various strategies to manage products at their end-of-life:

- repair, maintenance and refurbishment
- reuse and second-hand markets
- take-back programs for re-de-manufacturing and re-purposing
- material recycling and upcycling
- collaborations with recycling facilities
- energy recovery
- landfill avoidance

LIFECYCLE ASSESSMENT (LCA)

Life Cycle Assessment is a comprehensive analytical method used to evaluate the environmental impacts associated with all stages of a product's life, from raw material extraction (cradle) to disposal (grave). LCA is a valuable tool for assessing and minimizing the environmental footprint of products and services. As sustainability concerns grow globally, the role of LCA in guiding environmentally responsible choices is becoming even more critical. Here's an overview of LCA key issues:

- inventory analysis
- impact assessment
- strategic planning
- public policy
- marketing and communication

CLOSED-LOOP SUPPLY CHAIN AND OPEN-LOOP SUPPLY CHAIN

The Closed-loop Supply Chain is a key component of the Circular Value Chain. It refers to the system in which used products and materials are collected, processed, and reintegrated into the production process to create new products. The focus is on maintaining the value of resources and minimizing waste generation. Closed-loop supply chains involve processes like remanufacturing, recycling, and reprocessing, which enable the conversion of end-of-life products and materials into secondary raw materials or components. In a closed-loop supply chain, materials often go through multiple cycles of use, being continuously reprocessed and remanufactured. This approach reduces the demand for virgin resources, conserves energy, and lowers environmental impacts associated with extracting, processing, and transporting new materials.

In contrast to the closed-loop supply chain, the Open-loop Supply Chain follows a linear model where resources and products have a one-way flow, moving from production to consumption and eventual disposal. Once products reach the end of their life, they are discarded and often end up in landfills or incineration facilities, resulting in a loss of their value and contributing to waste and environmental pollution. The open-loop supply chain does not emphasize the recovery and reintegration of used products and materials into the production process. As a result, it leads to resource depletion, increased waste generation, and higher environmental impacts.

DECENTRALISED PLM

Decentralized Product Lifecycle Management (PLM) is an innovative approach to managing the entire lifecycle of products in a distributed and collaborative manner, without relying on a central authority or control. In the context of the Circular Economy, Decentralized PLM can significantly contribute to resource efficiency, sustainability, and circular practices by enabling better collaboration, data sharing, and decision-making among stakeholders throughout the product lifecycle. The following concepts attain to Decentralized PLM and its relevance to the Circular Economy:

- data transparency and trust
- provenance tracking
- end-of-life management
- extended product lifecycle
- Digital Product Passports
- efficient reverse logistics
- circular supply chains
- collaboration and data sharing
- smart contracts

DIGITAL PRODUCT PASSPORT

A 'Digital Product Passport' is a tool that centralises and digitalises all relevant information about a product throughout its life cycle. This is particularly useful in the circular economy where the aim is to maximise the efficient use of resources and promote the reuse, recycling and repair of products. Here are some key elements that could be included in a Digital Product Passport:

- basic product information
- technical information
- operating and maintenance instructions
- life cycle information
- end-of-life information
- environmental information
- economic information
- protection and safety
- traceability
- scalability
- data structure
- data analysis and artificial intelligence
- complex data models
- blockchain technology
- standardisation
- interoperability
- user interface and user experience
- use of open data formats
- upgrades and maintenance

DIGITAL TWIN

The concept of a Digital Twin is a powerful technological tool that can significantly impact the Circular Economy by optimizing resource management, enhancing sustainability, and supporting circular practices. In the context of the Circular Economy, a Digital Twin refers to a virtual representation or simulation of a physical asset, product, or system. It is a dynamic, real-time digital counterpart that mirrors the behavior, characteristics, and performance of its physical counterpart. Here's how the Digital Twin concept relates to the Circular Economy and its applications:

- product monitoring and simulations
- lifecycle management and design optimization
- lifecycle monitoring and analysis

- predictive maintenance and resource efficiency
- end-of-life management and recycling
- supply chain transparency and optimization
- feedback loops for continuous improvement
- product-as-a-service (PaaS) models
- AI and Machine Learning capabilities
- enabling service-based models
- consumer engagement
- circular business models

ASSET ADMINISTRATION SHELL

The Asset Administration Shell (AAS) is a central concept in the Industry 4.0 paradigm. It serves as the digital interface between the actual physical asset (like a machine, part, or system) and its data, functionalities, and services in the digital world. Here's the main concepts about AAS that we have deemed worth studying for the purposes of our work:

- data and metadata representation
- data integration, interoperability and standardization
- security and access control
- transparency and communication
- predictive maintenance
- end-of-life management
- supply chain transparency
- lifecycle traceability and information
- resource planning efficiency and optimization
- demand forecasting
- Digital Product Passport
- product-as-a-service (PaaS) models
- usage in connection to digital twins

BLOCKCHAIN

Blockchain is a decentralized and distributed ledger technology that allows data to be recorded in a secure, transparent, and tamper-resistant manner. It operates as a chain of blocks, where each block contains a list of transactions, and each block is linked to the previous one using cryptographic techniques. The decentralized nature of blockchain means that no single entity has full control over the network, enhancing its security and resilience. Here are some ways blockchain can impact the Circular Economy:

- product traceability and authenticity
- decentralized waste management
- supply chain transparency and optimization
- Digital Twins, asset tracking and monitoring
- transparency and trust
- collaboration and interoperability
- decentralized marketplaces
- data security and privacy
- regulatory compliance
- smart contracts for circular business models
- tokenization and incentives

DATA MODELS

Data models refer to structured representations of information related to resources, products, materials, and processes. These models help organize, analyze, and manage data in a standardized and coherent manner, enabling better decision-making, resource optimization, and sustainable practices. Data models play a crucial role in the Circular Economy by facilitating the flow of information, supporting circular business models, and promoting more sustainable resource management. We have examined the following topics related to data models and to their relevance to the Circular Economy:

- resource tracking and management
- resource and waste management
- supply chain transparency
- circular supply chain
- product lifecycle management
- environmental impact assessment and sustainability reporting
- standardization and interoperability
- regulatory compliance
- consumer engagement
- decision-making and predictive analysis
- enabling circular business models

DATA SPACES

A 'Data Space' is a key concept in the context of Industry 4.0 and the Circular Economy. It serves several functions to promote efficiency, transparency and advanced data management in circular processes. Aspects examined:

- data management, integration and standardisation
- data privacy and security
- data trust and sovereignty
- data interoperability
- secure transactions
- lifecycle traceability
- process optimisation
- supply chain transparency
- advanced digital twin management
- communication and transparency
- regulatory compliance
- reporting and compliance
- smart asset management

INDUSTRIAL DATA SPACE

The concept of the Industrial Data Space (IDS) is a framework that aims to facilitate secure and controlled data sharing and exchange in industrial environments. It provides a decentralized, standardized, and interoperable infrastructure for businesses to share and collaborate on data while maintaining data sovereignty and security. In the context of the Circular Economy, the Industrial Data Space plays a role in enabling the efficient and sustainable use of resources, supporting circular practices, and fostering innovation. Let's explore the concept of Industrial Data Space and its relevance to the Circular Economy:

- data privacy and security
- regulatory compliance
- data trust and sovereignty
- data interoperability

- secure transactions
- data-driven circular processes
- resource and waste management
- product lifecycle management
- transparent supply chain
- closed-loop supply chain
- product-as-a-service models
- smart asset management
- collaboration and partnerships
- consumer engagement

INDUSTRIAL DATA PLATFORM

The concept of an Industrial Data Platform (IDP) involves creating a centralized and standardized infrastructure for collecting, storing, processing, and sharing industrial data. It serves as a digital ecosystem that facilitates the integration and analysis of data from various sources within industrial environments. In the context of the Circular Economy, an Industrial Data Platform can support resource efficiency, sustainability, and circular practices by enabling better data-driven decision-making, collaboration, and optimization of industrial processes. Concepts related to Industrial Data Platform:

- data integration and interoperability
- real-time data collection, monitoring and analysis
- data analytics, visualization and security
- collaborative product development
- product lifecycle management
- lifecycle traceability
- predictive maintenance
- supply chain transparency
- regulatory compliance and reporting
- circular design and resource optimization
- circular business model implementation
- continuous improvement and innovation
- consumer insights for circular business models
- simulations
- decision-making and strategic planning
- marketplace for secondary materials
- smart asset management
- Digital Twins
- scalability

DATA INTEROPERABILITY

Data interoperability refers to the ability of different systems, applications, or organizations to exchange and interpret data seamlessly and efficiently. In the context of the Circular Economy, data interoperability facilitates the exchange of information between various stakeholders, such as manufacturers, suppliers, consumers, recyclers, and regulators. It ensures that data can be shared, understood, and used consistently across different platforms, enabling better collaboration, resource optimization, and circular practices. Let's explore the concept of data interoperability and its relevance to the Circular Economy:

- seamless data sharing
- product lifecycle management

- transparent supply chain
- integrated life cycle assessment (LCA)
- cross-industry collaboration
- circular business models
- metrics and reporting
- facilitating collaboration
- decision-making
- optimizing resource usage
- reducing redundancy & costs
- regulatory compliance
- consumer engagement

EXPLAINABLE AI

Explainable AI refers to the ability of AI models and systems to provide human-readable explanations for their decisions and predictions. It addresses the "black box" problem, where traditional AI models, such as deep neural networks, are often complex and challenging to interpret, making it difficult to understand how they arrive at specific outcomes. In the context of the Circular Economy, explainable AI has several important applications and benefits:

- sustainable resource management
- eco-design and circular product development
- circular supply chain optimization
- circular business models
- Circular Economy metrics and reporting
- circular innovation and research
- waste management and recycling
- recycling decisions
- product design
- predictive maintenance
- stakeholder trust
- regulatory compliance
- consumer engagement
- continuous improvement
- risk management
- collaborative decision-making

STRATEGY, CULTURE AND ORGANIZATION

For the construction of the PEOPLE and PARTNERSHIP pillars, we then examined some business aspects related to strategies, organisation, culture, personnel, which are transversal to all types of economy (thus not only of the Circular Economy), trying to define how they decline in the context of C.E.
The first of these is Strategy, with the aim of understanding whether the approach to C.E. is strategic, initial or occasional on the part of the SME.
We then have a culture and organisation question (how much of the company's culture and organisation is set up in a Circular Economy function) and an implementation question, which investigates to what extent the company has actually implemented Circular Economy initiatives.

STAFF AND SKILLS

A second set of questions investigates how the company relates to its staff in order to promote circularity, how it develops their skills and knowledge through training programmes, and how ethical principles inform the way it acts.

SUPPLIERS AND CUSTOMERS

For the purposes of the PARTNERSHIP pillar, as we will see in more detail in the next section, aspects of collaboration with customers and suppliers that characterise a circular relationship were investigated: type and depth of collaborations, level of involvement, etc.

IT PROVIDERS

IT Providers deserved a separate discussion. IT Providers play a significant role in the development of Circular Economy solutions for Small and Medium Enterprises (SMEs). IT solutions can support SMEs in their journey towards more efficient and sustainable resource management. Here are some ways in which IT Providers contribute to the development of Circular Economy solutions for SMEs:

- Traceability and Monitoring Systems
- Inventory and Procurement Management
- Sharing and Reuse Platforms
- Data Analysis and Artificial Intelligence
- Environmental Management Systems and Certifications
- Digital Training and Consulting

In practice, IT providers can help SMEs in the development of the typical aspects of the Circular Economy examined in this chapter.

As explained in the first part of this chapter, the topics listed and described above were analysed and discussed together with Circular Economy experts from the BATTERY, WEEE and PETRO pilots, and with POLIMI experts in assessment models and legal subjects, with the aim of understanding which of them to include in the survey and which to exclude as less of a priority (as the survey necessarily limited the number of possible questions), how to link them together, in what sequence, keeping everything in one coherent and sufficiently comprehensible thread; all of which produced the survey that we will describe in section 3.3 below, and which is set out in full in ANNEX 1 – “Circular Economy 6Ps” questionnaire.

3.3 The pillars of the new “Circular Economy 6Ps”

In section 3.2 above, we presented which aspects of the Circular Economy were studied and elaborated for the construction of the assessment tool. Let us now see how they were actually reported in the instrument, examining the 6 pillars one by one.

In ANNEX 1 – “Circular Economy 6Ps” questionnaire, you will then find all the questions and their answers.

3.3.1 The PRODUCT Pillar

In the PRODUCT pillar, specific product-related aspects of the Circular Economy were considered. In the original version of the 6Ps, the PRODUCT pillar referred to the incorporation of smart technologies in the product, such as sensors, connectivity, data processing and the consequent services that can be provided according to these characteristics. In this version, however, we took into consideration the product features that can characterise it as being part of a circular economy.

At the end of the analysis that was described in detail in the previous section, the dimensions incorporated were:

- **Product Design and Engineering**
- **Raw Materials**
- **End of Life**
- **Product Lifecycle Management and Digital Product Passport**
- **New Business Models enabled by the Circular Economy**
- **Use of data to enable new Business Models**

To each of these PRODUCT dimensions corresponds a question.
The answers to the 6 questions echo the themes illustrated in section 3.2, namely:

- material durability, sustainability and recyclability
- waste reduction
- use of scraps, co-products and by-products
- re-use, repair and refurbishment services
- energy efficiency and energy recovery programs
- re-use, re-manufacturing, de-manufacturing, disassembly, re-cycling
- Extended Producer Responsibility (EPR)
- traceability, transparency, end-to-end visibility
- verification systems
- collaborations with recycling facilities
- industry standards
- Product Lifecycle Management
- Digital Product Passport
- interoperable data exchange framework
- LCA (Life Cycle Assessment)
- PaaS (Product-as-a-Service), leasing and take-back programs
- consumers education and awareness

As can be seen, these are topics well relevant to the concepts of a product developed according to Circular Economy criteria.
The detailed questions of the PRODUCT pillar, with their answers, can be found in ANNEX 1 – "Circular Economy 6Ps" questionnaire.

3.3.2 The PROCESS Pillar

In the PROCESS pillar, some of the dimensions already present in the original version of the 6Ps have been retained: Design & Engineering, Production Management, Quality Management, Logistics and Supply Chain Management, but with very substantial modifications.
In the D&E dimension the question concerns the incorporation of Circular Economy concepts in the design processes of new products.
In the Production Management dimension, they were also included end-of-life management and product re-processing processes, typical of the Circular Economy.
The logistics dimension was transformed into a question on reverse logistics, because this aspect is very important in the Circular Economy.
The Supply Chain management questions have also been completely revised according to

the participation of Supply Chain tiers in Circular Economy processes.
There is also a question on after-sales services, which, in a circular logic, become a tool not only to offer additional services to the customer (also remunerated), but also to collect data on the product in order to better manage its life cycle.
The analysis dimensions incorporated in the PROCESS pillar were therefore:

- **Design and Engineering**
- **Management of Production and End-of-Life Re-Processing**
- **Quality Management**
- **After-Sales Services**
- **Reverse Logistics Management**
- **Supply Chain Management**

To each of these PROCESS dimensions corresponds a question.
The answers to the 6 questions echo the themes illustrated in section 3.2, namely:

- waste reduction
- repair and trouble-shooting services
- use of sustainable materials
- maintainability, durability and modularity
- repairability and recyclability
- eco-design
- Quality Control Systems
- traceability and transparency
- collection of product usage data
- product data analysis
- certifications and standardizations
- End-of-Life planning and management
- product up-grading, refurbishment
- Product re-processing and recycling
- product trade-ins and take back
- collaboration with suppliers and with recycling facilities
- lifecycle thinking
- feed-back loops
- customers engagement
- Digital Twins
- Digital Product Passport
- use of AGV and robots

The detailed questions of the PROCESS pillar, with their answers, can be found in ANNEX 1 – "Circular Economy 6Ps" questionnaire.

3.3.3 The PLATFORM Pillar

The PLATFORM pillar was completely reworked from the original 6Ps version on digital transformation. This, in fact, contained very technical questions aiming at investigating the level of digitalisation of the company's Digital Platforms, with the objective to define a tailored

roadmap for the transition toward a Digital Platform able to support both vertical integration (from the shop floor to the enterprise level) and horizontal integration along the value chain and end-to-end engineering. In this version of the 6Ps dedicated to the circular economy, however, we decided to include questions on the ICT technologies most typical in supporting circular processes.
In this case, the list of possible technologies was very wide, as there are many digital technologies that can support circular processes in SMEs; so, we decided to make a selection of the topics that are most typical and, at the same time, are widely dealt with in the Circular TwAIn Project, in order to maintain coherence between this task T2.4 and the other tasks of the Project.
The dimensions investigated in the PLATFORM pillar will therefore be:

- **Digital Product Passport**
- **Digital Twin**
- **Asset Administration Shell**
- **Data Spaces**
- **Industrial Data Platform**
- **Data Analytics**

To each of these PLATFORM dimensions corresponds a question.
The answers to the 6 questions echo the themes illustrated in section 3.2, namely:

- Digital Twins
- Digital Product Passport
- IoT
- Asset Administration Shells
- Data Spaces
- AI and Machine Learning
- data analytics
- traceability
- standardization
- interoperability
- data privacy and security
- data regulatory compliance
- data storage and management
- data encryption
- data trust and sovereignty
- predictive maintenance
- demand forecasting
- resource planning
- simulations
- PaaS (Product-as-a-Service)
- Blockchain
- Decentralized PLM

The detailed questions of the PLATFORM pillar, with their answers, can be found in ANNEX 1 – "Circular Economy 6Ps" questionnaire.

The three pillars described so far (PRODUCT, PROCESS, PLATFORM) are traditionally referred to as 'technical pillars'. The next three pillars (PEOPLE, PARTNERSIHP and PERFORMANCE) are referred to as 'Socio-Business' pillars; let us look at them below.

3.3.4 The PEOPLE Pillar

The first of the "Socio-Business" pillars is the PEOPLE, which has always been particularly relevant in the context of the 6Ps: transformation processes in companies, in fact, cannot ignore the involvement of staff: actually, staff, with their expertise, are the real drivers of transformation; when operating a transformation process, staff skills, training and involvement are the real heart of the change. With this pillar we therefore wanted to understand how the organisation is really Circular Economy-oriented in terms of strategy, organisation, actual implementation of real cases, and preparation of its staff.
The dimensions investigated in the PEOPLE pillar are:

- **C.E. Strategy**
- **C.E. Culture and Organization**
- **C.E. Implementation**
- **Staff and Expertise**
- **Skills**
- **C.E. Ethics**

To each of these PEOPLE dimensions corresponds a question.
The answers to the 6 questions echo the themes illustrated in section 3.2, namely:

- Strategy
- knowledge
- skills
- staff training
- culture
- adhesion to the principles of the Circular Economy Ethics
- roadmaps for the acquisition and development of C.E. capabilities
- programs and pilots
- continuous improvement
- skill assessments
- setting industry standards
- systems thinking
- promoting consumer education and awareness
- sustainable communication and marketing, circular finance, innovative thinking

The detailed questions of the PEOPLE pillar, with their answers, can be found in ANNEX 1 – “Circular Economy 6Ps” questionnaire.

3.3.5 The PARTNERSHIP Pillar

In the original version of the 6Ps, dedicated to the digital attitude of enterprises, this pillar investigated the propensity of SMEs to develop their projects in collaborative environments and to identify the partners needed for their transformation journey; in fact, collaborative

relationships with key stakeholders in the ecosystem help to create strong and collaborative partnerships.
In the version of the 6Ps dedicated to the Circular Economy, some changes have been made compared to the original version of the 6Ps dedicated to Digital Transformation, but without changing the general framework.
The following dimensions of analysis have therefore been retained:

- **Research & Innovation**
- **Training & Education**
- **IT Solution Providers**
- **Suppliers**
- **Customers**

whereas the question on collaboration with Digital Innovation Hubs was replaced with one on **Industrial Agreements**, more relevant to this project.

Although the structure of the questions has remained virtually unchanged, the corresponding answers have been modified in some cases to make them more consistent with the spirit of the Circular Economy. The themes included in the answers are therefore:

- participation in R&D programmes
- training
- involvement of IT Providers in the development of innovative solutions
- joint developments with suppliers and customers
- presence of Industrial Agreements and how they are implemented

The detailed questions of the PARTNERSHIP pillar, with their answers, can be found in ANNEX 1 – “Circular Economy 6Ps” questionnaire.

3.3.6 The PERFORMANCE Pillar

Finally, the PERFORMANCE pillar remained virtually unchanged from the original version.
This pillar aims at investigating what is the level of control over the company's processes and activities, also suggesting possible KPIs to measure the transition. KPIs are not only Operational and Economic, but also refer to the ability of the company to measure its performances over other aspects, such as Environmental, Social, Product-Service Lifecycle and performances of the entire Supply Chain. The pillar was left as it was because the original version had already developed Circular Economy topics as well.
The first two dimensions, Operational and Economics, cover indicators that are valid for any for-profit organisation, regardless of its scope and sector.
Then there are two dimensions, Environmental and Social, which certainly retain their interest in the Circular Economy as well.
Finally, the two dimensions Product-Service Lifecycle and Supply Chain respond perfectly to the spirit of the Circular Economy.
The dimensions examined therefore remain:

- **Operational/ Technical**

- **Economic**
- **Environmental**
- **Social**
- **Product-Service Lifecycle**
- **Supply Chain**

and the topics covered in the answers are:

- descriptive, diagnostic, predictive, prescriptive KPIs
- Life Cycle Costing (LCC)
- environmental LCA
- social LCA
- sustainability and Green Deal
- sustainability and integration along the Supply Chain

The detailed questions of the PERFORMANCE pillar, with their answers, can be found in ANNEX 1 – "Circular Economy 6Ps" questionnaire.

3.4 "Circular Economy 6Ps" Transformation journey

The survey methodology is very similar to that already framed for the 6Ps Digital Transformation. The aim is to build a starting point and a basis for new ideas and roadmaps towards circularity. The tool should help the enterprises identify their gaps towards the Circular Economy, since it is required to evaluate both the current and the expected level, for each pillar and dimension.
The methodology is based on five main steps:

1. **Set-up of a team bringing together different organizational areas**: identification of the staff able to answer the different sections of the assessment tool.

2. **Identification of the AS-IS profile of the enterprise**: the current profile must be mapped into each dimension and development stage of every pillar.

3. **Definition of the target TO-BE profile of the enterprise**: the future vision and desired profile of the manufacturing enterprise must be defined considering the links to the business and competitive priorities, and thus mapped onto each dimension and development stage of the 6P pillars.

4. **Identification of actions, feasibility and prioritization**: this step is about identifying the actions needed to migrate from the AS-IS to the TO-BE and considering the links to the business strategy as well as benefits and costs, risks and dependencies, evaluating to what extent investments are justified and what actions should be prioritized.

5. **Development of the Migration Plan towards Circularity**: finally, the migration plan is developed. To this respect, different approaches can be adopted. Often, the most successful is to focus on simple actions with short-term pay-offs at first (quick wins)

before implementing more complex and long-term projects.

This above is the complete methodology, which is not necessarily carried out in its entirety. The first three steps form the basis of the work and are, of course, mandatory.
Depending on the results obtained and the actual interest raised by the tool, the company may decide whether to proceed to step 4 (identification of priority actions) and then to the definition of an actual migration plan (step 5).

3.5 "Circular Economy 6Ps" Output

As in the case of the 6Ps for Digital Transformation, the output of CE6Ps is in the form of radar charts (Figure 11).

A radar chart is produced for each Pillar, on whose axes the analysis dimensions are shown, each with its AS-IS (blue line in the figure) and TO-BE (orange line) scores.
As it can be seen, the radar charts analytically highlight the results on each dimension.

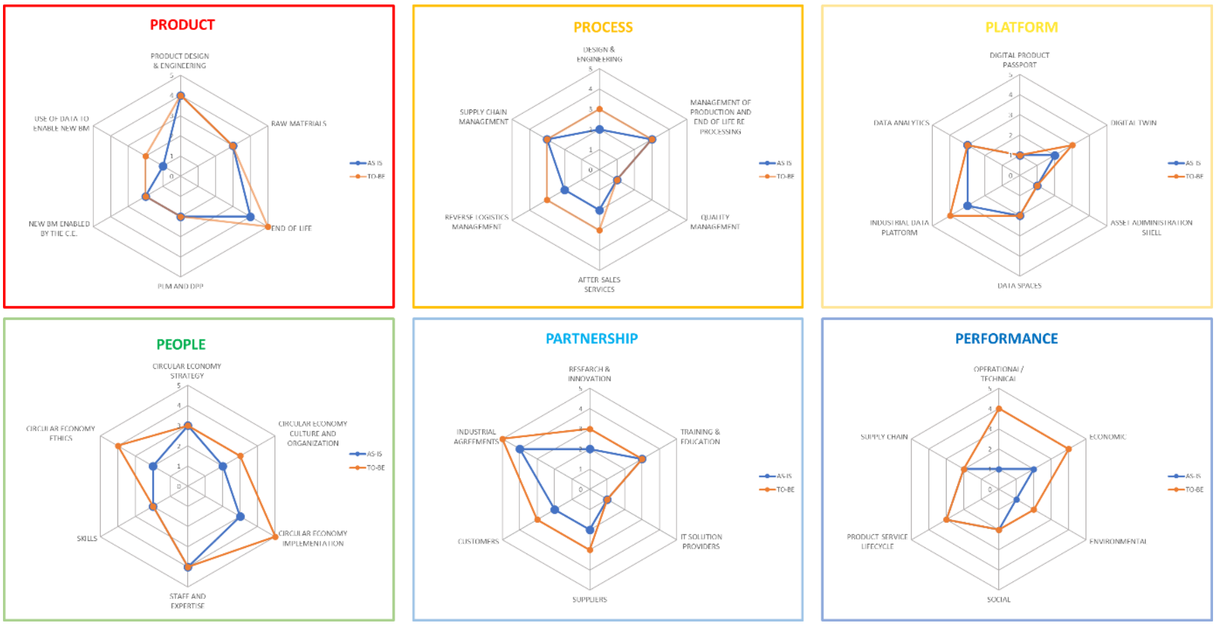

Figure 11 – The CE6Ps Output – one chart per pillar

It is also possible to have a single graph with the aggregate view, as in Figure 12.

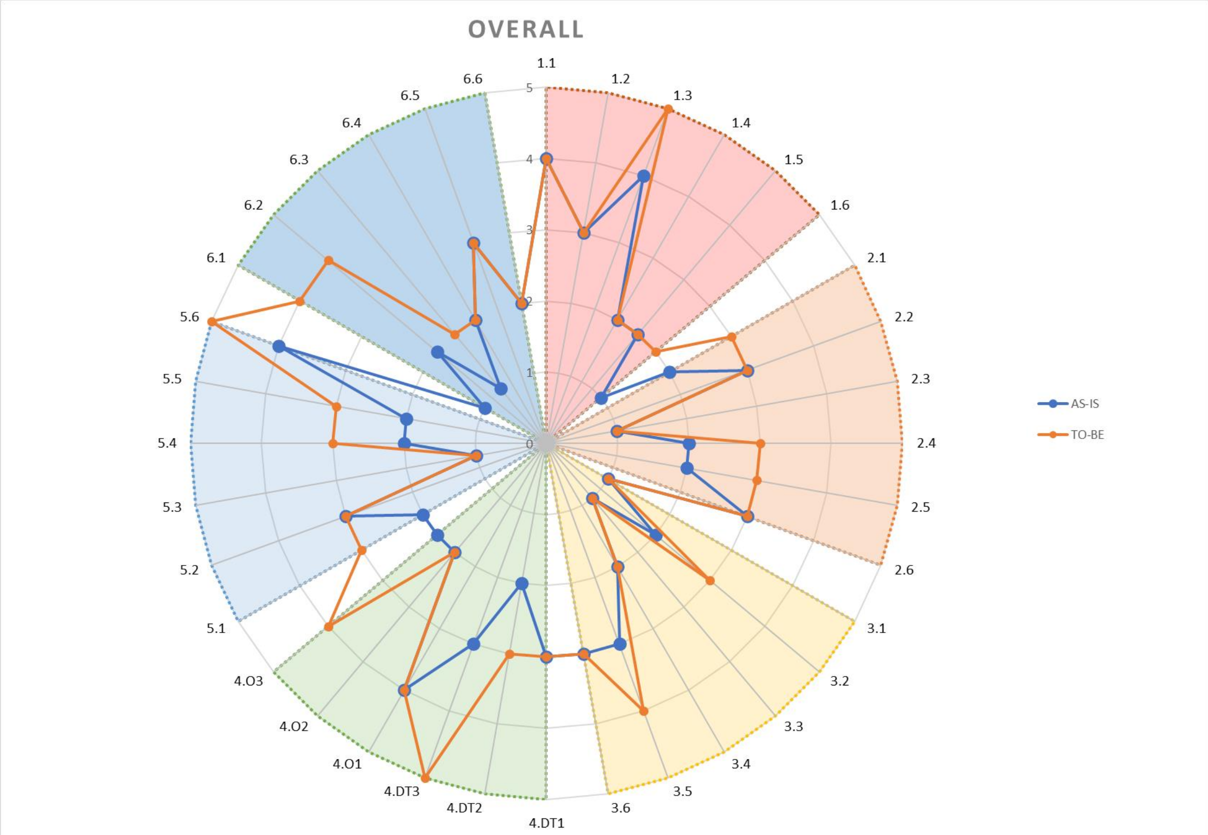

Figure 12 – The CE6Ps Output – pillars aggregate view

The type of scale used is the same as already seen for the Digital Transformation 6Ps, i.e. (see Chapter 2 for the descriptions of these levels):

Maturity Level 1: Initial

Maturity Level 2: Managed

Maturity Level 3: Defined

Maturity Level 4: Integrated

Maturity Level 5: Exploited

Finally, a representation is possible that highlights the areas for improvement, quantifying them. In the following block diagram, one can see the predominance of the areas and dimensions in which the greatest improvements have occurred, in proportion to the area of each block; the 'non-applicable' or 'non-impacted' dimensions (i.e., not assessable in the company or in which AS-IS = TO-BE) are not shown in this diagram.

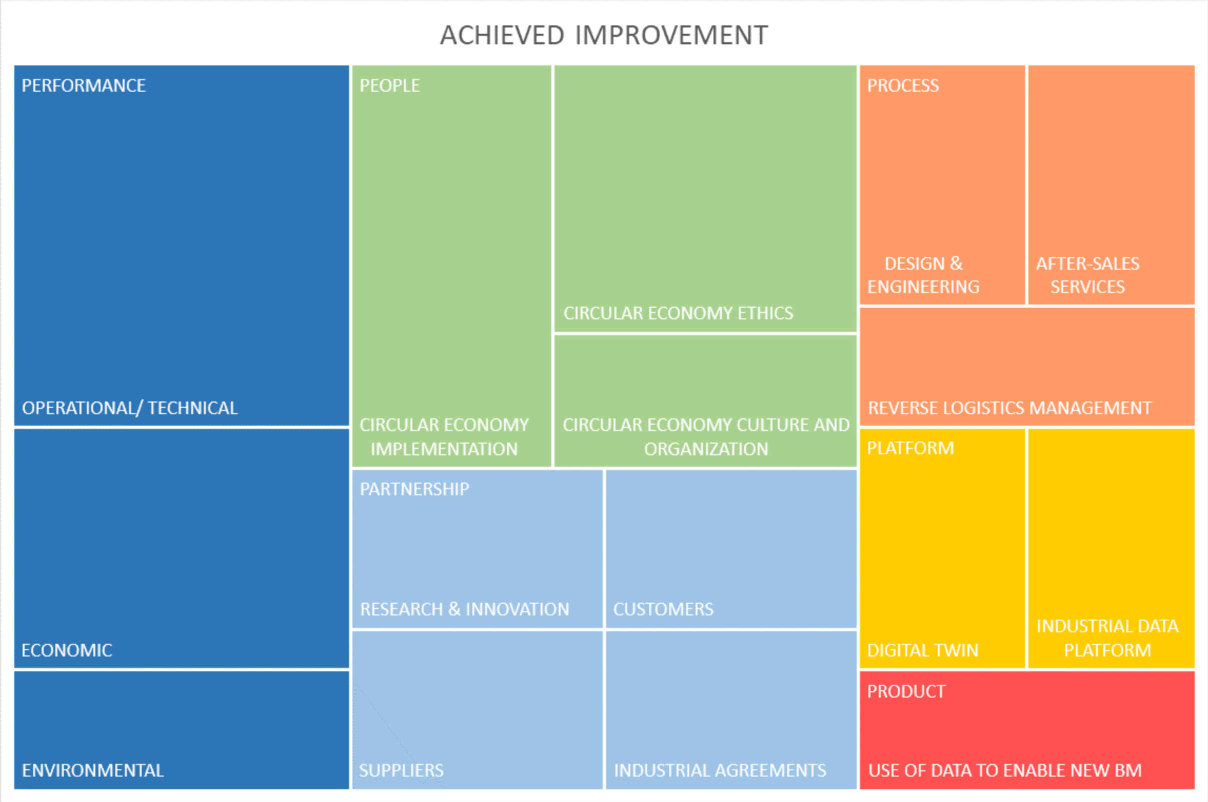

Figure 13 – The CE6Ps Output – improvement blocks

The C.E. 6Ps offers a broad and comprehensive system of indicators, not limited to technical and economic aspects alone; the 6Ps extends its arm to aspects related to personnel, external collaborations, and social-environmental impact.

The tool not only takes a snapshot of the organization's current level with respect to all the dimensions examined ("AS-IS"), but also requires identification of the levels of evolution the organization intends to achieve thanks to the pilot in progress ("TO-BE"). The gaps to be bridged between AS-IS and TO-BE constitute the organization's transformation path. This path is immediately apparent through the representation of the results in the form of radar diagrams, which provides an overall view of all the areas examined (the 6 "pillars"), helping understand the level of internal coherence of the strategy, and offering an intuitive and immediate view of the transformation paths that the organization will follow.

Thus, the 6Ps can be considered both an assessment tool, because it measures the maturity of the organization in the various dimensions of analysis (AS-IS), and a tool that suggests concrete ideas and helps the organization focus on its transformation path.

4 Circular TwAIn Pilots and Use Cases

4.1 Introduction

According to the DoA, T2.4 (Socio-technological-business-ethical continuous assessment and 6Ps Transformation) "will define roles, responsibilities and procedures for assessing the socio-economic and ethical impact of the Enterprises involved in the experiments. The 6Ps model (AI REGIO) for Digital Transformation assessment and benchmark will be extended and tailored for the Circular Economy application domains. In particular, the model will establish the impact of AI technologies on Products, Processes, Platforms, People, Partnerships, Performance in a Circular value chain."

The Task envisages the development of a version of the 6Ps tailored to Circular Economy, and its subsequent implementation in two phases: a first iteration, which is to take place at the end of the M7-M18 period, and which is the subject of this deliverable, and a second iteration, which is to take place towards the end of the project, and which will be the subject of deliverable D2.4.

The purpose in running two iterations is to have a first impact assessment at the beginning of the pilot, in which the pilot leaders will give answers according to their expectations; thus, the values attained by the organisation before the start of the pilot (AS-IS) and those expected to be achieved at the end and thanks to the pilot (Expected TO-BE) will be quantified. In the second iteration, which will take place when the pilots have been completed or are in the process of completion, the values actually achieved by the organisations thanks to the pilots (Actual TO-BE) shall be indicated. In the processing of the results of the second iteration, the values of the Expected TO-BE shall be compared with the Actual TO-BE, thus obtaining additional insights beyond the simple results of the pilot. By examining the actual results and comparing them with the expected results, we shall be able to:

- measure the real impact of the pilots on the companies; where the progress was, why, how it was achieved;
- assess the vision and planning capacity of the pilot leaders: goals achieved, deviations from expected results, possible corrective actions;
- the next iteration of the 6Ps will thus result in not only an analysis of the type already seen in this deliverable, but, in addition to it, an analysis of whom performed best in terms of actual results vs. expected results, trying to analyse and explain the reasons in relation to the typicalities of the pilot;
- further improving the development and use of the 6Ps model, including devising new applications of it.

As already explained in the previous chapter, numerous members of the consortium (POLIMI, ENG, NISSATECH, SUITE5, NOVA, INTRA, GFT, RECYCLIA, REVERTIA, EAI, TEKNOPAR, COBAT, SOCAR, RAEEMAN, AIMEN) participated in the development of the tool, some of whom were also the recipients of the compilation of the first iteration. Therefore, the joint setting up of the tool made it possible to illustrate the tool itself and its questions to future compilers, thus ensuring that they arrived at compilation already prepared, without the need for further training.

Let us briefly summarise below the pilots who were the recipients of the compilation; we will do so in a concise manner, as the pilots are extensively and comprehensively described in other deliverables.

4.2 Battery

The Circular TwAIn battery pilot is focused on the circular value chain of e-mobility Li-Ion battery packs.

Automotive battery systems are complex components and their circular value chain is peculiar: they share with the rest of the vehicle only the central part of the linear value chain (assembly, distribution, usage). Their manufacturing and end-of-life management instead, follow dedicated routes. The current circular value chain for automotive battery systems lacks optimization in the recovery of functionalities and materials from these components. Nevertheless, it already excludes both landfilling and energy recovery as viable options. Nowadays, batteries are managed by a transport and logistic actor which ensures their distribution to an authorized dismantler for discharge and disassembly. Finally, the battery modules or battery cells, core of the whole system, undergo pyrometallurgical recycling for the recovery of target cathode metals, especially Co.

The concept behind the Circular TwAIn battery pilot is to overcome the current value chain by integrating innovative Circular Economy nodes of the following framework:

- E-mobility battery systems which reach their end-of-life are collected by transport and logistics operators.
- Preliminary tests assess the reusability of the battery without any manipulation. The compliant batteries are directly reused in automotive or stationary domains.
- Those battery packs whose direct reuse is not applicable are disassembled and tested at modules and eventually cells level.
- The units (modules and cells) suitable for reuse are reassembled in second life batteries.
- The units with no residual electric properties compliant for reuse are recycled exploiting combined mechanical and hydrometallurgical processes for a more efficient recovery of raw materials.

This pilot involves five use cases:

- Computer-vision driven collaborative robotics for the disassembly of LIB packs
- Machine learning aided automated disassembly of LIB modules
- AI tool for the characterization of the LIBs state-of-health combining historical and testing data
- AI tool for optimized mechanical recycling of degraded LIBs
- Market oriented holistic decision-support-system for the LIBs de- and re-manufacturing

The consortium members involved in this pilot are: POLIMI, COBAT and RAEEMAN.

4.3 WEEE

WEEE management is the safe, technological, and scientifically sound methods to remove/dispose the electronic waste from the environment. It includes reusing, refurbishing, and recycling at the end of the product life. The WEEE management service can be divided into four steps:

1. Hassle-Free pickup: This recycling process step consists of study and planning the collection of the WEEE in efficient way, so the client ongoing activities and business processes are least disturbed.
2. Individual waste management: The main aim of this step is to extract the maximum value from the collected WEEE waste. This is performed by first deleting information and secondly by life cycle analysis.
3. Waste treatment: this is the major step of the WEEE management. In this step a comprehensive audit is conducted for information collection regarding the product and components. This information mainly consists of the technical characterization and possible defects associated with the product and components.
4. Documentation: All process and steps are documented with relevant indicators highlighted in the life cycle analysis and compliance with the regulations.

A considerable amount of WEEE is in the form of personal computers both at domestic and commercial levels. Such devices are highly modular with standard components and sub-components.

The reuse, recycle, and/or remanufacturing of personal computers are a laborious yet skilful process. In most of the cases, such operations are manually handled, and the operators use standard mechanical and electrical tooling to disassemble the components one after another. The remanufacturing process is subjective and mainly selected based on the operator experience and skills.

This pilot involves five use cases.

The consortium members involved in this pilot are: REVERTIA, RECYCLIA and AIMEN.

4.4 Petro

EO/EG plant of SOCAR was put into operation in 1985 and has a production capacity of 89.000 tons of MEG yearly. The process of the EO/EG plant is based on the "Shell's direct oxidation " process. Ethylene and pure oxygen are mixed and passed through a multitube catalytic reactor to produce EO selectively, and then at high pressure and temperature Ethylene Oxide and water are reacted to produce Ethylene Glycols. The main raw materials are ethylene and oxygen. The end products, mono-ethylene glycol (MEG) and di-ethylene glycol (DEG), are used in the production of Antifreeze, Polyester fiber, PET bottles, Textile Products.

TEKNOPAR will bring its expertise in developing open digital twin pipeline development architecture to be used as a baseline platform to acquire data from various IoT devices, sensors, DCSs, MES and therefore contribute to the development of a Hybrid Circular Twin (HCT) for process industry that will be verified in PETKIM Use Case Pilot.

SOCAR will provide its PETKIM Ethylene Oxide/ Ethylene Glycol EO/EG) plant, for the piloting activities (WP6). The developed frameworks and modules will be implemented in the EO/EG plant with supervision of TEKNOPAR. SOCAR will also contribute to collection of data, model development, AI/analytics application, generation of a scheduling tool for optimization and verification of the system.

This pilot involves five use cases:

- Data acquisition and representation for AI framework
- Developing a hybrid circular twin of the process

- Use of data analytics, AI and model verification to understand process unit failures
- AutoML module for Process Industry
- Generation of a tool for process optimization

The consortium members involved in this pilot are: SOCAR, TEKNOPAR.

5 Conduct of the assessment

5.1 Introduction and participants

The conduct of the assessment took place quickly due to the fact that there were only 4 compilers and that, as explained in the previous chapter, all had already been involved in the preparation of the assessment tool through meetings that took place in June-December 2023, and thus had sufficient familiarity to compile it.

Our approach was to ask the consortium members involved in the pilots to make a single compilation that included all the use cases for which they were responsible. Responses were to be given by reasoning about the impact the set of use cases had on their respective organizations.

Considering the distribution of use cases within the pilots, the compilation was therefore carried out by: REVERTIA (WEEE), SOCAR (Petro), COBAT (Battery), RAEEMAN (Battery).

5.2 Online compilation and results processing

As mentioned in the introduction, the completion of the assessments was conducted online. The compilers received the following link to a Qualtrics SW for online surveys, much in use at POLIMI's:

https://polimi.eu.qualtrics.com/jfe/form/SV_3UvNtZmZPWHar2e

Upon accessing the survey, one is introduced by a Welcome page that explains the purpose of the questionnaire within the Circular TwAIn Project, followed by a page of biographical and sectoral data of the compiler's company (Figure 14).

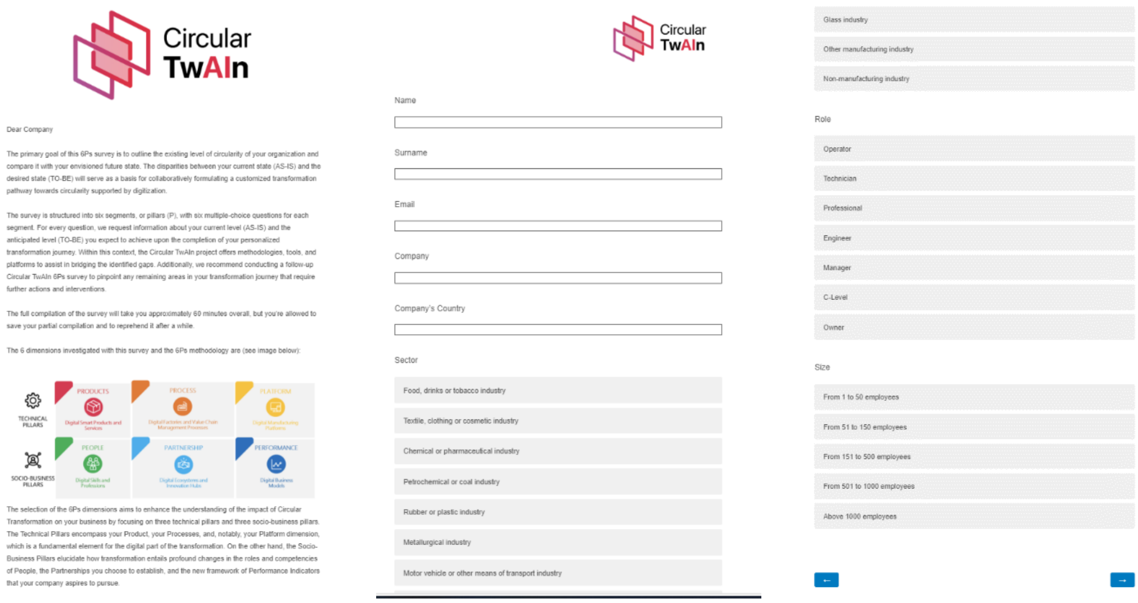

Figure 14 – 6Ps questionnaire: Welcome pages

Then, the respondent has access to the six sections (also named "pillars") of questions: PRODUCT, PROCESS, PLATFORM, PEOPLE, PARTNERSHIPS, PERFORMANCES.

The questions are presented as in the example in Figure 15 (which shows the first question of the PRODUCT pillar). Each question, corresponding to a dimension of analysis, has 5 levels of response, corresponding to increasing levels of digital maturity; for each question there is the “Not Applicable” option, in case the question is not applicable to the pilot or SME in question.

The questionnaire gives the option of skipping sections that are not applicable to the context of the pilot, as we can see in Figure 16.

Figure 15 – First questions (PRODUCT pillar)

Figure 16 – Front page of the PROCESS section

The tool also gives the option of saving and resuming later, in case more than one colleague, each with his or her own expertise, was needed for its compilation.
When the compilation is complete, the compiler decides whether to definitely save the results, in which case they are received on a dedicated Qualtrics Data & Analysis page, from which POLIMI’s analysts can develop their own elaborations.

The results were collected in Qualtrics, in excel and pdf format, and subsequently analysed. The excel results are used for graph processing, in the form shown in Section 3.5 and which we will see in Chapter 5 in their concrete application.
New excel sheets, adapted to the new context and the new questions and answers, were prepared for the processing of the excel results. These excel sheets were processed both in a single use case version and in a version that merges all use cases, for aggregate analyses, as we normally do in all projects.

The pdf results are sent to the compilers for their feedback.

The outcome of all these concepts will be shown in detail in the following Chapter 6, in which we illustrate the results.

6 Presentation of results

This chapter will present the results of the compilations by the three pilots (COBAT and RAEEMAN for Battery, REVERTIA for WEEE, and SOCAR for Petro).
We will begin, in 6.1, with an analysis of the aggregate results of the 4 compilations, both in overall view and in detail by pillar, and then examine, in 6.2, the individual responses of the pilots.

6.1 Analysis of the aggregate results by pillar and dimension

Let us begin with an overview of the aggregate results (average of the results of the 4 compilations).
This type of analysis is useful because it allows us to understand the impact of the Circular TwAIn Project on its members in general, and which pillars and dimensions are most impacted by the Project.
Of course, because we are talking about average values, this view does not provide nuances and detail, which can only be understood by going into the analysis on a per-use-case basis, but it is useful to begin to frame the topic.
Figure 17 shows the average results of the 4 compilations; the blue line indicates the AS-IS values (at the beginning of the pilot); the orange line the Expected To-BE (or "ETB" hereinafter) values, i.e., those expected to be reached at the end of the pilot.

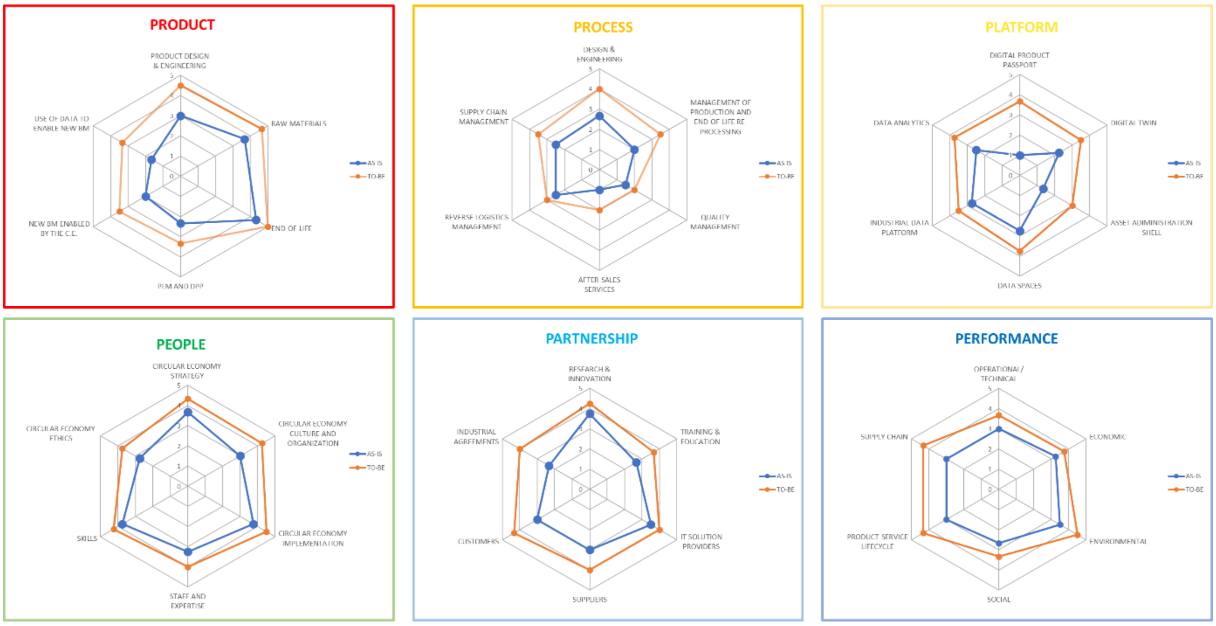

Figure 17 – Aggregate results of the 3 pilots

From Figure 17 we can derive the following observations (again remembering that these are average values, not point values of a single case):

- the Circular TwAIn Project impacts, as predictable, all the pillars and dimensions examined by this assessment;
- although Circular TwAIn is a Project with important technical content, respondents predict that the pillars with higher TO-BE value will be the socio-business rather than the technical ones; indeed, we observe that the largest orange areas are in PEOPLE, PARTNERSHIP, PERFORMANCE and also in PRODUCT (the latter is a technical

pillar), while the boxes PLATFORM and, especially, PROCESS are slightly narrower;

- above all, the PROCESS result may come as a bit of a surprise, given that the Circular TwAIn Project has, evidently, a strong process connotation; the Circular Economy does, in fact, leverage precisely business processes to transform business behaviour from linear to circular;
- upon closer inspection, however, we observe that the gaps expected to be filled in the three technical pillars are greater than the gaps expected to be filled in the socio-business pillars;
- in the three technical pillars, in fact, the difference between Expected TO-BE and AS-IS is 1.3 points for PRODUCT (which goes from an AS-IS of 2.8 to an ETB of 4.1), 1.0 points for PROCESS (from 2.0 to 3.0) and 1.4 points for PLATFORM (from 2.1 to 3.5);
- putting the three technical pillars together, their average AS-IS value is 2.3; the average Expected TO-BE value is 3.5; the average increment is 1.2; thus, we go from AS-IS values slightly above 2-MANAGED to ETB values intermediate between 3-DEFINED and 4-INTEGRATED;
- in the three socio-business pillars, although the three orange areas are greater, progress is, on average, less, because the starting AS-IS values were higher;
- in PEOPLE we observe an increase of 0.8 (from an AS-IS of 3.4 to an Expected TO-BE of 4.2), in PARTNERSHIP of 1.0 (from 3.0 to 4.0) and in PERFORMANCE of 0.9 (from 3.1 to 4.0);
- the average AS-IS value of the three socio-business pillars is 3.2; the average Expected TO-BE value is 4.1; the average gap is 0.9;
- the gaps expected to be made up are, therefore, greater in the technical pillars than in the socio-business pillars.

Table 1 shows the numerical data in a better readable form:

		PRODUCT	PROCESS	PLATFORM	PEOPLE	PARTNER	PERFORM.
average among pilots	***AS-IS***	*2,9*	*2,7*	*2,4*	*3,4*	*3,3*	*3,3*
	TO-BE	*4,1*	*3,7*	*3,7*	*4,2*	*4,1*	*4,0*
st. dev. among pilots	***AS-IS***	*0,6*	*1,2*	*1,8*	*0,4*	*1,1*	*0,8*
	TO-BE	*0,6*	*1,3*	*1,4*	*0,8*	*1,0*	*0,5*

Table 1 – Average AS-IS and Expected TO-BE values, per pillar

At the AS-IS level we see the difference between the three **technical pillars** and the three **socio-business pillars**; these differences decrease at the TO-BE level, where of data tend to converge on more uniform averages.
Similarly, it can be seen that the standard deviation (which measures the dispersion among the pillars) also tends to decrease (indicating a convergence of values not only among pillars, but also among pilots), although this is not a trend common to all pillars.

Figure 18 gives us a better understanding of the balance among the pillars in a single view; there is a fair degree of uniformity along all dimensions (indicating that all pillars are relevant to the project), but it is evident that the left side of the chart (green-sky-blue, the three socio-business pillars) is more "meaty" than the right side (pink-orange-yellow, the three technical pillars).

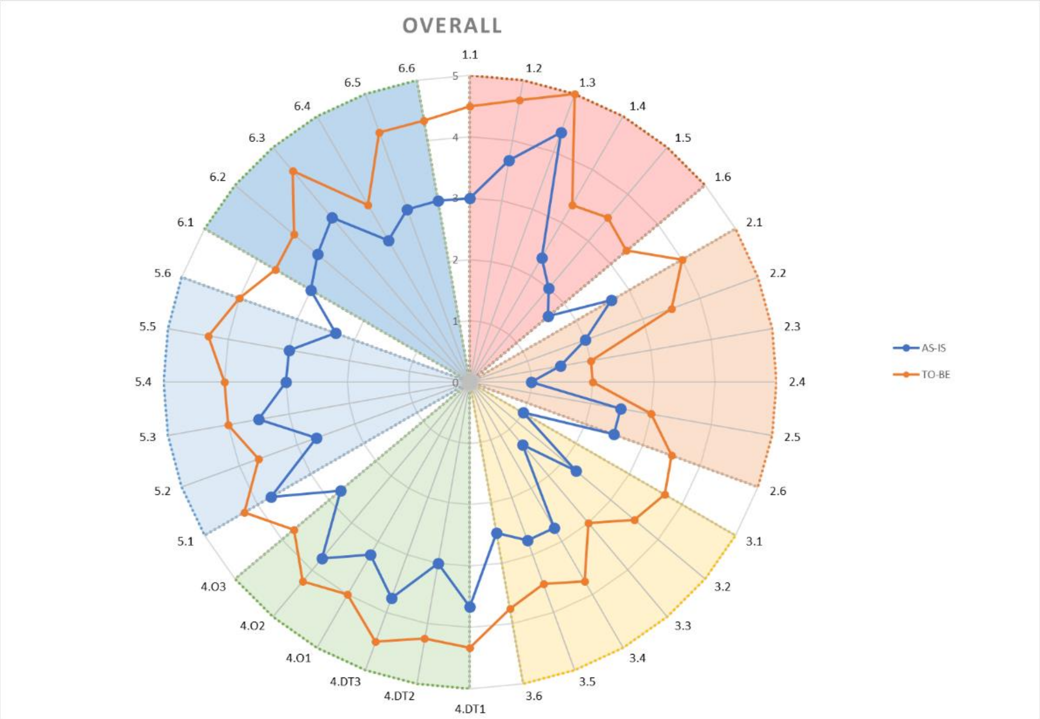

Figure 18 – Aggregate results of the 3 pilots – Overall view

Our explanation of these results is as follows.

The companies who took part in Circular TwAIn Project did so with the aim of developing products, processes and platforms in circular function.

These are companies with a predisposition toward the circular economy (as we can understand from the high AS-IS scores of PEOPLE-Strategy, PEOPLE-Culture, PEOPLE-Skills), which already have fruitful collaborations with external partners in place (PARTNERSHIP pillar) and the ability to monitor their own processes (PERFORMANCE pillar), but which needed a collaborative environment within Europe to develop products, processes, and technologies; this explains why the three technical pillars start with lower average AS-IS values than the socio-business pillars, but then achieve higher increases.

We can imagine that if said companies had had high levels of circular maturity of their products, processes, and ICT solutions before the Circular TwAIn Project, they possibly would not have been particularly interested in joining it.

In the next paragraphs we will go into detail about the individual pillars with their dimensions, again at the aggregate level.

6.1.1 PRODUCT

In the PRODUCT pillar, there is an obvious pattern (Figure 19).

The first three dimensions (Product Design & Engineering; Raw Materials; End-of-Life), which are closely related to product development, are more developed than the next three (PLM and DPP; New Business Models; Use of Data), which are typical of a more advanced stage of development.

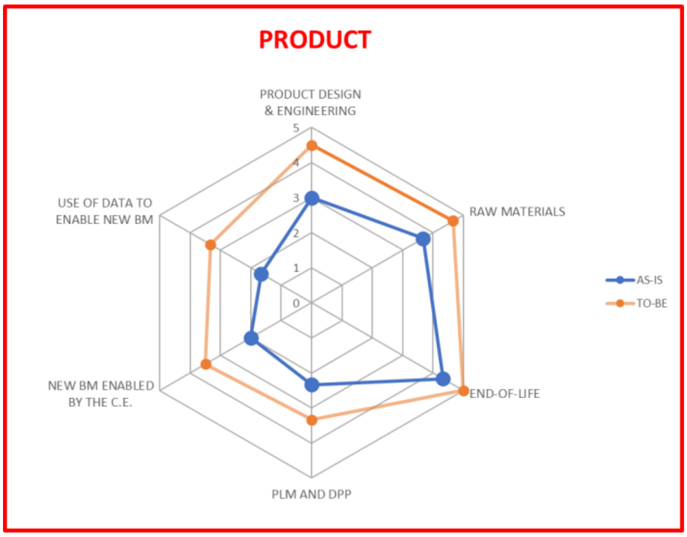

Figure 19 – Aggregate results of the 3 pilots – The PRODUCT pillar

On average, dimension **1.1 – Design & Engineering** grows from an AS-IS value of 3-DEFINED (indicating that the company considers the principles of durability, energy efficiency, sustainability, and recyclability of materials in its D&E processes) to ETB values of 4.5, indicating the ability to design new products with a view to reuse, remanufacture, de-manufacture, disassemble, recycle, and with reference to user requirements and industry standards.

Dimension **1.2 – Raw Materials**, passes from the already high AS-IS value of 3.7 (presence of guidelines for the use of raw materials and adhesion to the principles of Extended Producer Responsibility) to an even higher ETB value of 4.7, corresponding to the adoption of Circular Economy principles like traceability, transparency, verification systems, somehow optimizing the use of resources in a continuous improvement process.

In dimension **1.3 - End-of-Life**, the highest scores in this entire assessment are achieved, going from an AS-IS 4. 3 (higher than INTEGRATED: established system for reuse, repair, remanufacturing, and refurbishment of products; collaborations with recycling facilities; energy recovery programs) to an ETB value of a full 5, indicating an established system for reuse, repair, remanufacturing, and refurbishment of products; collaborations with recycling facilities; energy recovery programs; presence of take-back programs for de-manufacturing and reuse. Note that the mean value of 5 means that all pilots that considered this question applicable believe they will be able to achieve a level of full exploitation of the End-of-Life dimension at the end of the pilot.

The next three dimensions of this pillar report substantially lower values than the first three, but for different reasons.

In the first case (dimension **1.4 - PLM and DPP**), which concerns the adoption of advanced tools such as PLM and Digital Product Passport, the average value at the beginning of the project is 2.3 (PLM and DPP are in an implementation phase, with attempts to integrate product data throughout the product life-cycle, to implement product traceability and end-to-end visibility) to an ETB 3.3 (data integration between Product Lifecycle Management and Digital Product Passport in progress, leading to improved end-to-end visibility and product traceability). This well describes the expected evolution over the course of the Circular TwAIn Project, and how it is expected to deliver this level of improvement.

In the 5th and 6th dimensions the scores are lower, however, because they concern aspects of Business Models that at this stage of the project are, rightly, not yet developed, and may be if the project is successful.

Dimension **1.5-New Business Models enabled by C.E.**, highlights an initial 2-MANAGED level (existence of pilot projects) and expects to have developed, by the end of the project, circular business models such as PaaS, leasing or take-back programs, possibly redesigning the supply chain and rethinking the product life cycle to prioritize sustainability and resource efficiency.

Dimension **1.6 - Use of Data to enable new Business Models** moves along with the previous one; the goal is to move from an AS-IS level 1.7, where new simple business models are being enabled by digital systems involving e.g. only specific system suppliers, to an ETB 3.3, well above DEFINED, where new business models have been enabled by digital systems managing one-to-one data exchanges and potentially, all possible circular operators (system suppliers, component suppliers, circular material suppliers…) could be involved.

6.1.2 PROCESS

As mentioned above, the PROCESS pillar started, on average, from a more backward AS-IS situation than all the others. Its average level at the beginning of the project was, in fact, 2.0.
Let us analyze it dimension by dimension (Figure 20).

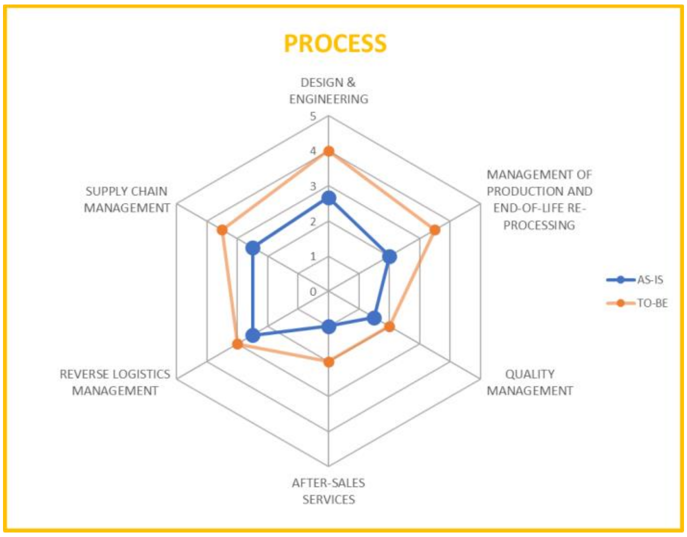

Figure 20 – Aggregate results of the 3 pilots – The PROCESS pillar

Dimension **2.1 - Design & Engineering** is the highest in terms of both AS-IS and ETB (Expected TO-BE), rising from 2.7 (some lifecycle thinking and eco-design in the product development, taking into account maintainability, durability and modularity; or, at least, prioritization of waste reduction and use of sustainable materials) to 4.0 (product lifecycle thinking embedded from the design stage, including circularity elements like modularity, durability, maintainability, repairability and recyclability; possible adoption of Digital Twins),

with an important progress of 1.3 points.
Note that this question is about the company's approach to the Design & Engineering process as a function of C.E., while question 1.1-D&E seen in the previous pillar was about incorporating circular features into the product. Normally, although the two things are not the same, there should be consistency between the answers given to these two questions, and in fact we observe that in question 1.1 we have AS-IS = 3.0, ETB = 4.5 and GAP = 1.5, while in this one we have AS-IS = 2.7, ETB = 4.0 and GAP = 1.3, values that we can consider absolutely consistent.

Dimension **2.2 - Management of Production and End-of-Life Re-Processing** sees an expected improvement from 2.0 to 3.5, with a significant increase of 1.5 points.
The AS-IS level = 2.0 shows that, always on average, the company has started adopting some founding concepts like sustainable materials selection, traceability, standardization and modularity; ETB 3.5 indicates the ambition to implement connections among production processes, product end-of-life management and product re-processing and to establish reverse logistics and take-back programs, thus building a true operational structure on foundations already laid.

In dimension **2.3 - Quality Management** we observe a limited progress of 0.5 points; it is expected to move from an AS-IS of 1.5 (a situation where they are beginning to implement a quality control system that also incorporates C.E. principles) to an ETB 2.0 (a Quality Control System is implemented in a Circular Economy perspective).
It may be that this dimension, while important, was not valued by respondents because it is believed that the QCS already in place is also sufficient from a Circular Economy perspective.

Dimension **2.4 - After-Sales Services** starts from absolutely initial levels (1.0), but the response is biased by the fact that only one of the 4 respondents considered this question Applicable, while the others did not answer. Since there was only one response out of four, it is not worth dwelling now on the analysis of this dimension at the aggregate level. However, we can make one general point: not enough attention was paid to this question by the respondents. In fact, the question asked, "How does your company manage the after-sales services to customers for monitoring and managing the life-cycle of its products?" and provided, as a level 1-INITIAL answer, that the company still adhered to a linear model. It is therefore hardly understandable why 3 out of 4 respondents considered selecting the response Not Applicable to a process that, necessarily, must exist in the company (as it is unimaginable that manufacturers would completely disregard the product once it leaves the factory), instead of opting for the 1-INITIAL response, which would have been more understandable.

As visible in the diagram, the last two questions, on Reverse Logistics and Supply Chain, highlight advanced start and finish levels, compared to this group.

Question **2.5 - Reverse Logistics Management** sees limited progress (0.5), but starts from respectable AS-IS values (2.5), indicating the existence of systems for registration and stock management of returned products, as well as integration of data from different sources with the use of data analysis tools; ETB ranks 3.0, meaning that they expect a full integration of data from different sources, with the use data analysis tools so as to achieve a greater understanding and more efficient management of reverse logistics operations.

Finally, dimension **2.6 - Supply Chain Management** shows that the surveyed companies start, on average, from values between MANAGED and DEFINED (2.5, use of recycled, reusable or renewable materials; services to extend product life; raw materials suppliers are assessed based on their sustainability practices and resource efficiency) and expect an average progress of 1.0 points, adding to existing activities integrated forms of collaboration with suppliers and with recycling facilities.

Overall, in the end, the average Expected TO-BE of this pillar comes to be 3-DEFINED, a progress of 1.0 points, certainly significant, which allows the PROCESS pillar to realign, almost, with the terminal values of the other 5 pillars.

6.1.3 PLATFORM

The PLATFORM pillar (Figure 21) had, at the beginning of the Circular TwAIn Project, average AS-IS values among the six dimensions of 2.1, only just higher than the PROCESS pillar. At the same time, it is the one in which respondents expect the greatest progress: a remarkable +1.4, which would bring the ETB to 3.5.

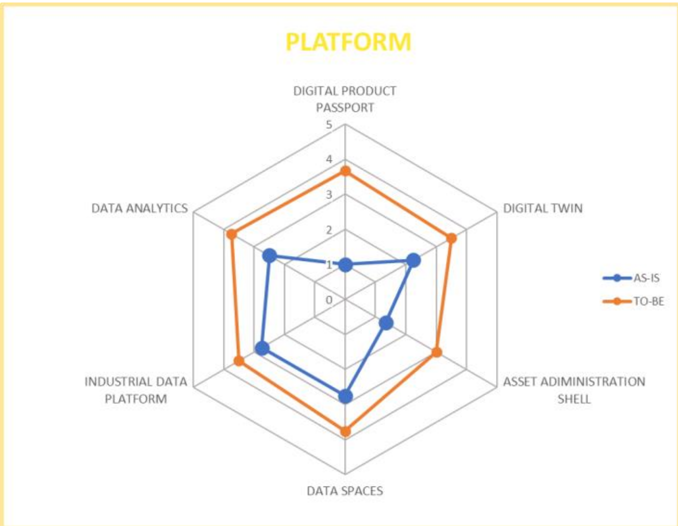

Figure 21 – Aggregate results of the 3 pilots – The PLATFORM pillar

From the diagram we observe that AS-IS values are quite different across dimensions, while ETBs tend to align; this is a good thing, as it demonstrates the intention to uniformly develop the sophisticated ICT technologies available to support C.E.

Question **3.1 - Digital Product Passport** shows us that all respondents were, at the beginning of the project, at an absolutely INITIAL level (1.0), where DPP is not adopted and traditional documentary methods are employed instead. Here, however, it is predicted a dramatic progress (at least in the average) of 2.7 points, the highest among all the 36 dimensions examined. The ETB is placed at 3.7, a level where DPP was developed to enhance traceability and end-of-life management; standardization, interoperability and use of open data formats are applied. These responses are consistent with the nature of the Circular TwAIn Project, which in fact sees the development of DPPs as one of the cornerstones of its efforts to maximize the efficient use of resources and promote the reuse, recycling and repair of products.

Similarly, dimension **3.2 - Digital Twin** investigates another cornerstone of the Circular TwAIn Project, the adoption of Digital Twins in business processes, a tool that can have a significant impact on the Circular Economy by optimizing resource management, improving sustainability, and supporting circular practices. In this case we start from AS-IS levels above 2-MANAGED (adoption of Digital Twins, for real-time monitoring and simulations of products to optimize some processes, has already started), and the goal is to reach an ETB of 3.5 (Digital Twins integrated with IoT to optimize the approach to product lifecycle management, product design, predictive maintenance and forecasting, possibly equipped with AI and learning capabilities). The gap to be bridged is smaller than the previous dimension (1.3), but here we start from a higher AS-IS level.

Dimension **3.3 - Asset Administration Shell** appears slightly weaker than the others, but we must keep in mind that this is still a developing technology. Respondents start at an average AS-IS level of 1.3 (little more than INITIAL in this topic, which seems logical), but hope to progress, over the course of the project, to an ETB of 3.0, a level that is fully DEFINED and almost aligned with the scores achieved in the other dimensions (AAS is part of company's practices; data and metadata are standardized): the purpose is to provide real-time control of assets or processes and support resources optimization and products lifecycles management.

The next two dimensions, Data Spaces and Industrial Data Platform, were the most familiar to respondents at the start of the project, partly because they are among the building blocks of the project itself.

3.4 - Data Spaces has a mean AS-IS level of 2.8 (close to DEFINED: Data Spaces integrate data from different sources within the circular processes, enabling real-time visualization of the circular ecosystem) and an ETB of 3.8, thus indicating that they are intended to incorporate data processing and analysis capabilities for the optimization of circular processes, possibly including the integration of concepts of Data Trust and Sovereignty. This major advance is not surprising, given that Data Spaces are essential constituent elements for the exchange and sharing of data in collaborative business processes, serving crucial functions in promoting efficiency, transparency and advanced data management in circular processes.

Dimension **3.5-Industrial Data Platform** also starts from AS-IS value of 2.8 (Industrial Data Platform with well-defined policies, standards, and procedures, capable of integrating data from different sources and enabling real-time data monitoring and analysis), to reach average ETB value of 3.5, where data interoperability is addressed, enabling circular process optimization and advanced functionality. This progress is also among the expectations as the IDP serves as a digital ecosystem that facilitates the integration and analysis of data from different sources within industrial environments and plays a crucial role in promoting resource efficiency, sustainability and circular practices, enabling better data-driven decision making, collaboration and optimization of industrial processes.

The last dimension of this technical pillar, which is also essential, is **3.6 - Data Analytics**. Of course, these capabilities were already well known at the beginning of the project, so much so that they start from an average AS-IS 2.5 (analytics techniques are used to filter and visualize data sets and sometimes for forecast/prediction models). Expected TO-BE reaches 3.8 (the highest in this pillar along with Data Spaces), indicating capabilities of forecast and prediction based on AI/Machine Learning models relying on data ingestion and data storage, for instantiating what-if analysis.

6.1.4 PEOPLE

With the PEOPLE pillar we enter the three Socio-Business pillars (Figure 22).
As explained at the beginning of this chapter, this pillar highlights the propensity of consortium members toward the Circular Economy because it examines aspects related to strategy, organization, culture, skills, and actual implementation of circular economy processes in the company.
The propensity is demonstrated by both the starting values at the beginning of the project (average AS-IS 3.4) and the Expected TO-BE (average ETB 4.2), which are maximum in both cases compared to all other pillars.
We now come to the detail of the individual dimensions.

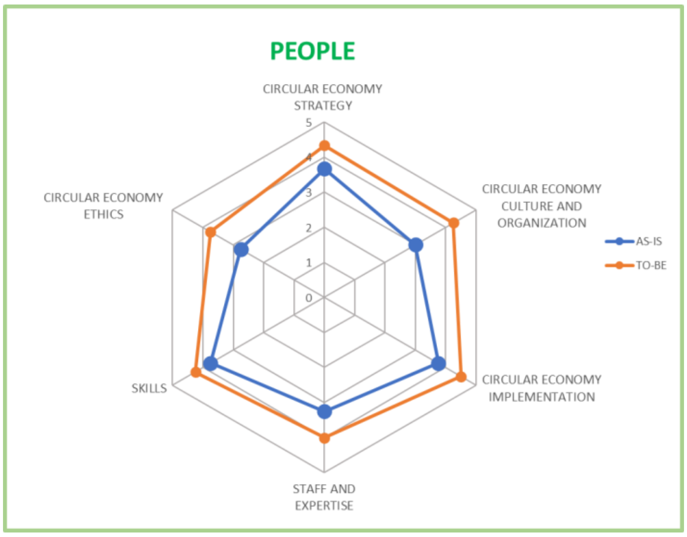

Figure 22 – Aggregate results of the 3 pilots – The PEOPLE pillar

Regarding **4.1 - Circular Economy Strategy**, the average AS-IS is 3.7, indicating that the C.E. was already assuming, before the CT project, a key role in business strategy; the average ETB reaches a score of 4.3: that is, the members intend to concretize the C.E.'s key role through the opportunities provided by the project.

Answers to dimension **4.2 - Circular Economy Culture and Organization** tell us that the organization already expresses a culture and organization oriented toward C.E. (AS-IS = 3. 7), having defined a set of roles and tasks among staff who have specific Circular Economy skills, and that it also plans to improve this aspect by creating functions or SBUs dedicated to Circular Economy, with the task of supporting all other functions or SBUs, including employee training (ETB = 4.3).

This response is well reflected and consistent with what we see in the following dimension

4.3 - Circular Economy Implementation, which starts from an average AS-IS value 3.8 (programs to collect and recycle materials and reuse products, in collaboration with Supply Chain levels) and points to ETB 4.5 (in addition to the above activities, results are monitored with dedicated KPIs and there is participation in setting industry standards for sustainable products and promoting consumer education and awareness).

Competencies (**4.4 – Staff and Expertise**) start from an existing situation where the skills needed for our projects are already identified and acquired, and there are staff training programs and/or skills assessment systems (AS-IS 3.3), and aim to be integrated with roadmaps for the acquisition and development of Circular Economy skills, consistent with strategic plans (ETB = 4.0).

Staff skills (**4.5 - Skills**) are already highly developed, as was predictably needed to contribute effectively to the Circular TwAIn project; the average AS-IS is 3.8 (knowledge and management of materials, use of sustainable technologies, eco-design; capabilities of data analysis) and is expected to be further developed with the deployment of systems thinking skills geared especially to Supply Chain management (ETB 4.3).

The last question is about the consideration given to ethical issues (**4.6 - Circular Economy Ethics**); the level that emerge from the responses show due attention to the issue: AS-IS 2.8 (Circular Economy Ethics and its value principle of sustainable development are systematically part of the processes) and there are plans to improve them to an ETB 3.8 (establish new production ethics guidelines and protocols to reflect ethical attitudes toward resources, environment, production and consumption).

6.1.5 PARTNERSHIP

This pillar aims to investigate what is the current and desired level of engagement by the company's external stakeholders, with the goal of establishing a roadmap for identifying the partners needed for a transition to the Circular Economy.
The responses (Figure 23) show very advanced levels both of the AS-IS (pillar average of 3.0) and of the Expected TO-BE (pillar average of 4.0).

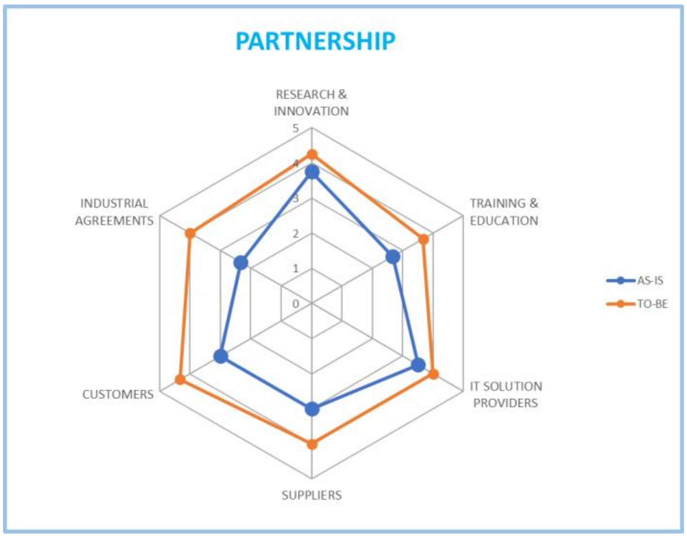

Figure 23 – Aggregate results of the 3 pilots – The PARTNERSHIP pillar

The first dimension, **5.1 - Research and Innovation**, starts from AS-IS levels close to 4-

INTEGRATED (collaboration in Research & Innovation projects involving data collection, data sharing and data analytics), which is expected to be systematized (ETB = 4.3).

Collaboration with educational and training institutions (**5.2 - Training and Education**) targets progress from 2.7 (presence of skill assessment and training programs for some C.E. roles) to learning programs planned with educational institutions (ETB = 3.7).

Responses to question 5.3 on the role of IT Providers (**5.3 - IT Solution Providers**) consistently reflect what is happening in the project, as they are estimated to be of great importance; the value before the project began was already 3.5 (joint developments with IT providers) and will be raised to an ETB 4.0 (development of data exchange platforms, endowed with Data Analytics and AI capabilities).

Responses on the SC tiers (**5.4 - Suppliers** and **5.5 - Customers**) are also consistent with a Circular Economy approach, as they already show high levels of collaboration with suppliers and customers (AS-IS 3.0 in both cases), which will be brought to ETB 4-INTEGRATED. At these levels, there are strategic partnerships with suppliers and customers in order to achieve Circular Economy goals, such as: joint product development, closed-loop systems and collaborative efforts.

The last dimension of this pillar, **5.6**, investigates typical aspects of the C.E., **Industrial Agreements**.

The Industrial Agreements aim to regulate relations with other industry players with a view to adopting common standards for voluntary business-to-business data exchange schemes and to develop a sectoral data space to foster cooperation, and will therefore be very important in the context of the CT project. Respondents are aware of this, and in fact have given this dimension scores that demonstrate a willingness to adapt to these requirements, so that from a starting AS-IS level that is not high (2.3, meaning that only informal communication and one-off share of information is established) it is intended to grow, on average, to ETB values of 4.0, with which the company is engaged in bi- or multi-lateral contractual frameworks.

6.1.6 PERFORMANCE

CE6P's PERFORMANCE dimension aims at investigating what is the current and the desired level of control over your company's processes and activities.

Also this pillar, like the previous socio-business pillars, shows the achievement of important levels, as both AS-IS and Expected TO-BE, by our pilot group (Figure 24); the average AS-IS value is 3.1 (DEFINED) and the ETB 4.0 (INTEGRATED).

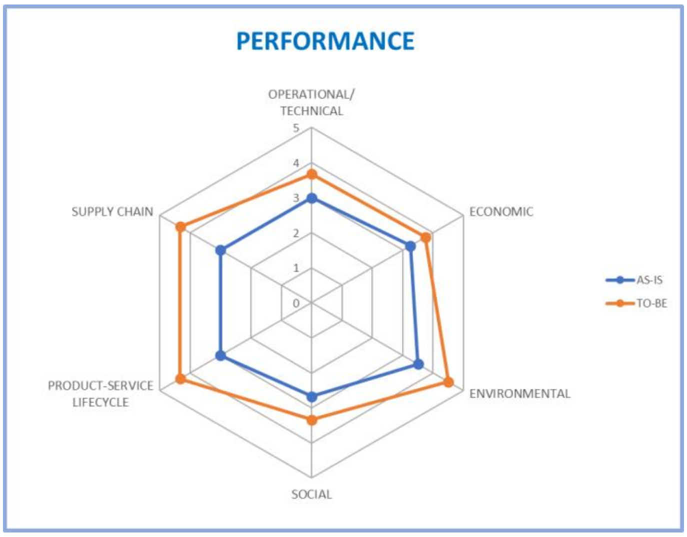

Figure 24 – Aggregate results of the 3 pilots – The PERFORMANCE pillar

The first dimension **6.1 - Operational/ Technical KPIs** started from AS-IS 3.0 (DEFINED) values, indicating a diagnostic approach to measuring operations, with an attempt to understand the causes that affect events and behaviours, and is expected to reach an ETB 4.0 (INTEGRATED), corresponding to a predictive measure of performance, in which statistical models and forecasts techniques to understand the future KPIs can also be used.

Dimension **6.2 - Economic KPIs** started from AS-IS 3.3 values, indicating a diagnostic/predictive approach to measuring operations, able to understand the causes that affects events and behaviors, and it is expected to reach an ETB 3.8 (close to INTEGRATED), corresponding to a predictive measure of performance.
These first two indicators, typical of any manufacturing company, demonstrate that the project participants had instructed advanced levels of control in the company even before the project, which will allow them to fully measure and understand the benefits and improvements brought by the pilots to their respective organizations.

The next indicator, **6.3 - Environmental KPIs**, is where the highest levels of both AS-IS and ETB are found. The AS-IS is a remarkable 3.5 (between DEFINED and INTEGRATED), indicating the ability to make diagnostic/predictive measures, with a clear understanding of the causes of events and the possibility of integrating them with predictive statistical models; the ETB reaches a score of 4.5 (intermediate between INTEGRATED and EXPLOITED), with functionality therefore also prescriptive in nature, helping the organization to find the best course of action thanks to simulation and optimization tools. These responses, which denote high attention to environmental issues, are consistent with participation in a C.E. project such as Circular TwAIn.

Dimension **6.4 - Social KPIs**, has moderate scores as both AS-IS (2.7 the aggregate mean, slightly below DEFINED) and ETB (3.3, slightly above DEFINED); thus, we are on diagnostic levels.

As expected, dimension **6.5 - Product-Service Lifecycle** achieves high scores instead, consistent with the aims of the Circular TwAIn Project. The AS-IS is 3.0 (DEFINED): we start (again, on the average of the 4 respondents) with the ability to measure Life Cycle Costing

(LCC) towards recycling and/or de- re-manufacturing, and aim to achieve at least the ability to measure, in addition to Life Cycle Costing, the Environmental LCA towards Circular Economy (ETB = 4.3)

Dimension **6.6 - Supply Chain** is also closely relevant to this project, and in fact it achieves very significant scores, like the previous one. AS-IS is 3.0 (DEFINED) and ETB 4.3 (above INTEGRATED), indicating the goal of moving from physical and economic measures of SC performances (purchase price, non-quality costs, delivery delays, lack of flexibility, etc.) to measures that also include sustainability for almost all the suppliers.

In summary, the diagram in Figure 25 allows us to better appreciate the impact of the CT project generally on all dimensions examined and also the dominance of technical pillars as to expected progress. The chart highlights the areas for improvement, quantifying them; improvements are proportional to the area of each block; dimensions that are "not applicable" or "not impacted" (i.e., not assessable in the company or where AS-IS = TO-BE) are not shown in this chart.

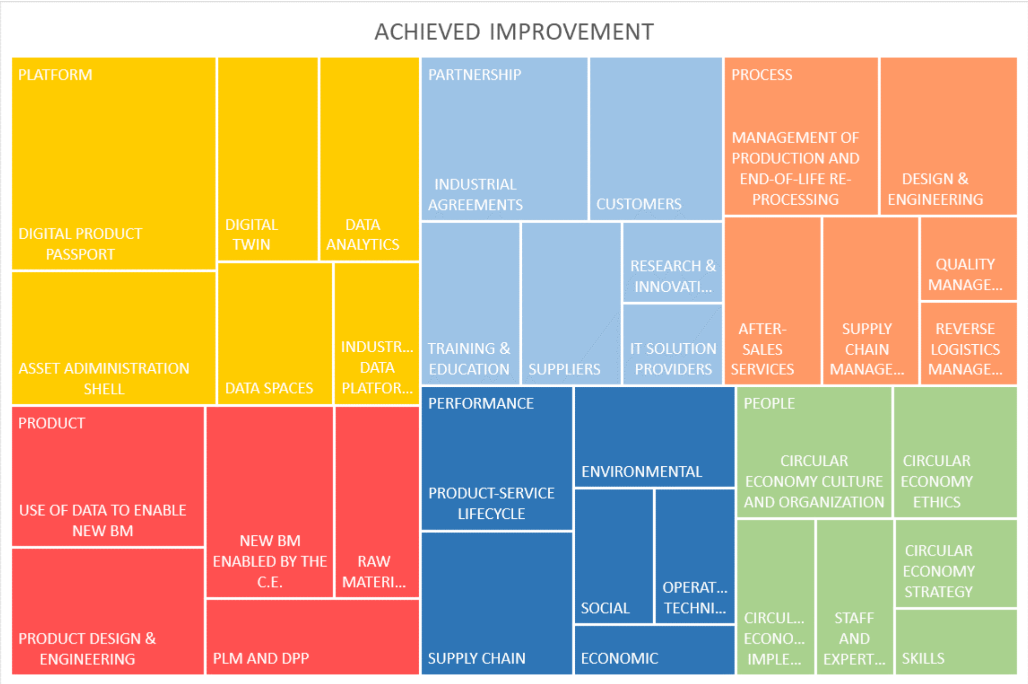

Figure 25 – Aggregate results of the 4 compilations – Highlighting the expected progress

6.2 Analysis by pilot

Having examined the overall impact of the Circular TwAIn Project on the pilots through an aggregate view, we turn to the analysis of the responses of individual use cases.
As described in Chapter 5, the following compilations were received from the pilots:

- **Battery - Cobat**
- **Battery – Raeeman**
- **WEEE – Revertia**
- **Petro – Socar**

We will now look at them one by one.

6.2.1 Battery - Cobat

The results of this compilation are shown in the diagram in Figure 26.

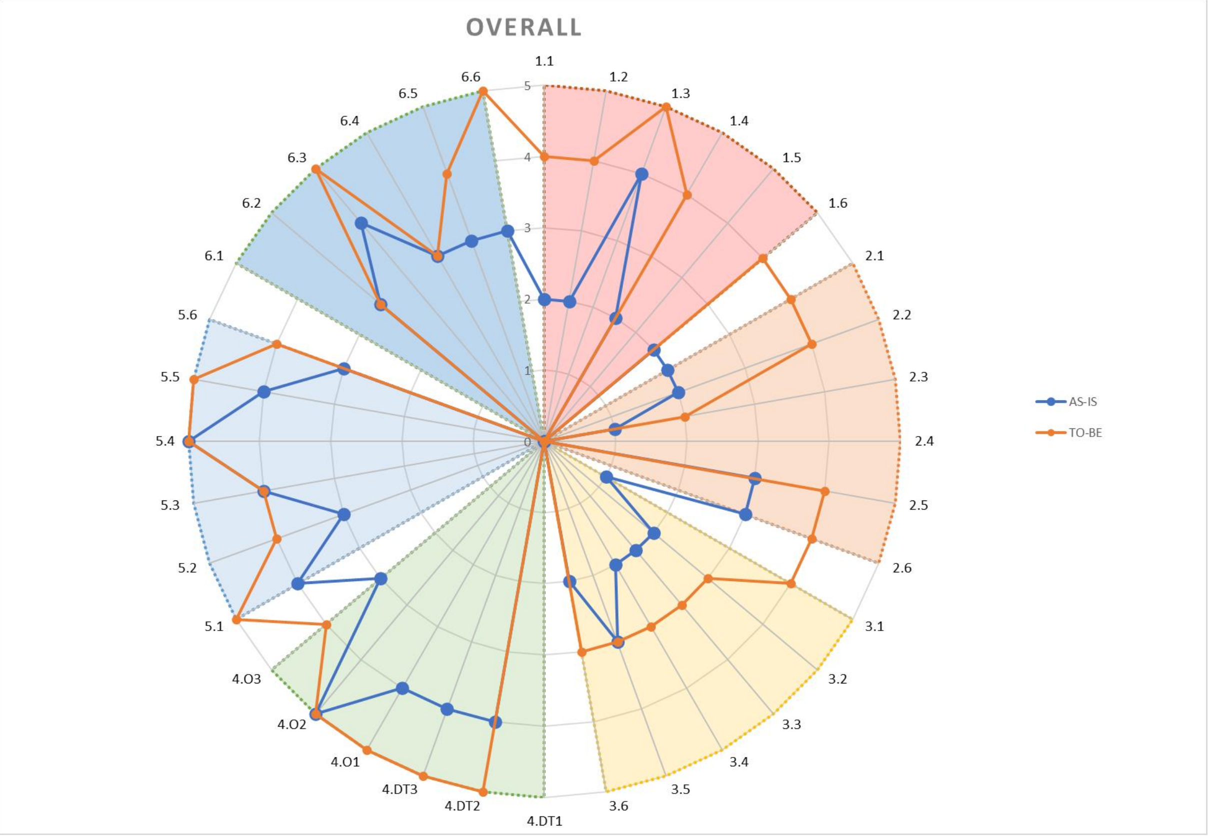

Figure 26 – Battery – Cobat Overall Results

We observe a pattern similar to the aggregate pattern (described in section 6.1 above): the left side of the diagram (socio-business pillars) appears more "meaty" than the corresponding right side (technical pillars) at the AS-IS level, but these differences are, at least in part, recovered in the ETB scores.

This pattern can be well read in Table 2 below, which shows the AS-IS values (average in the pillar), the Expected TO-BE values (also average in the pillar) and the corresponding gaps.

	AS-IS	Exp. TO-BE	Gap
PRODUCT	2,4	4,2	1,8
PROCESS	2,2	3,6	1,4
PLATFORM	2,0	3,2	1,2
PEOPLE	4,0	4,8	0,8
PARTNERSHIP	3,8	4,5	0,7
PERFORMANCE	3,2	4,0	0,8

Table 2 - Battery – Cobat Avg. Results in the pillars

This means that Cobat intends to build on existing solid foundations to develop a circular

economy.
The propensity toward C.E. is evidenced by the high scores in the Socio-Business pillars, which cover corporate culture, organization and skills (PEOPLE), the existence of partnerships and collaborations with external stakeholders (PARTNERSHIP) and a structure ready to measure performance (PERFORMANCE).
Development toward C.E., on the other hand, is seen by the progress expected to be made in the technical pillars (PRODUCT, PROCESS, PLATFORM), which are clearly evident in both Figure 26 and Table 2. In particular, the Gaps column shows the significant leaps forward that are expected in the first three pillars.

In the **PRODUCT** pillar we see that Cobat assigns an AS-IS 2-MANAGED level to 4 out of 6 dimensions: Product D&E, Raw Materials, PLM and DPP, Use of data to enable new BMs. The company is already working on concepts of durability, sustainability, and/or recycling, and is committed to waste reduction and the use of scrap, co-products, and by-products; PLM and DPP are being implemented to achieve product traceability and end-to-end visibility; and digital systems are in place to enable new C.E.-related business models.
In all these dimensions, the goal is to move to a 4-INTEGRATED ETB, which means the ability to design new products with a view to reuse, remanufacture, de-manufacture, disassemble, recycle, and with reference to user needs and industry standards; there are guidelines to optimize the use of primary and recycled raw materials; Circular Economy principles in raw material management, such as traceability, transparency, verification systems, and EPR will be adopted; PLM and DPP are managed in a connected way, where data integration is well established, providing complete end-to-end visibility and traceability of products; new business models are expected to emerge, enabled by digital systems that implement an interoperable data exchange framework.
End-of-life, on the other hand, is already on a very advanced level: it starts with an AS-IS equal to 4-INTEGRATED (established system for product re-use, repair, re-manufacturing and refurbishment; possible collaborations with recycling facilities and energy recovery programs) and is aiming for an ETB 5-EXPLOITED, corresponding to a full exploitation involving take-back programs for de-manufacturing and re-purposing. Cobat is therefore focusing heavily on the recycling and end-of-life management aspects of the product, and intends to strengthen them through the CT project.

Major progress is also expected in the **PROCESS** pillar, especially in the functions D&E and Production Management integrated with Product End-of-Life management and reprocessing. These two activities are moving from a 2-MANAGED AS-IS (waste reduction and use of sustainable materials; some foundational concepts such as sustainable material selection, traceability, standardization, and modularity) to a 4-INTEGRATED ETB (life-cycle thinking incorporated from the design phase, including circularity elements such as modularity, durability, maintainability, repairability, and recyclability; possible adoption of Digital Twins; integration of manufacturing processes, product end-of-life management, and product reprocessing).
Quality Management (question 2.3) is already considered quite adequate, moving from an AS-IS = 1-INITIAL to an ETB = 2-MANAGED, in which the Quality Control System manages material selection and production processes from a Circular Economy perspective.
The two dimensions 2.5 and 2.6 (Reverse Logistics Management and Supply Chain Management) are quite interrelated, and in fact had similar responses. In both cases, there

are plans to move from an AS-IS 3-DEFINED (integration of data from different sources and use of data analysis tools that enable good understanding and efficient management of reverse logistics operations; raw material suppliers are evaluated based on their sustainability practices and resource efficiency) to an ETB 4-INTEGRATED (reverse logistics in operation for product repair, returns, remanufacturing, and recycling; advanced data analytics to optimize routes and time; transparency; collaborations with suppliers and recycling facilities; reverse logistics systems to manage product returns, repairs, remanufacturing, and recycling, enabling optimized material flows and resource use).

Significant progress is also expected in the **PLATFORM** pillar, as, on average, we move from an AS-IS 2-MANAGED to an ETB 3.2, above DEFINED.
The most important development is that of the Digital Product Passport, which, as seen in the diagram in Figure 26, moves from 1-INITIAL (DPP not adopted) to 4-INTEGRATED (Digital Product Passport consolidated to improve traceability and end-of-life management); this is a definite expected outcome among the CT project goals.
Four out of six dimensions (Digital Twin, AAS, Data Spaces, and Data Analytics) grow from 2-MANAGED (i.e., there has already been a start on these technologies, with some basic implementations) to 3-DEFINED: adoption of Digital Twin integrated with IoT; AAS as part of business practices; Data Spaces capable of integrating data from different sources within circular processes; prediction and forecasting models for instantiating "what-if analysis," relying on data ingestion and data storage. It is appreciable to see how these four dimensions are developed harmoniously and consistently with each other and with the other technical dimensions.
Also consistent is the response on the Industrial Data Platform, which remains at a 3-DEFINED level (well-defined policies, standards and procedures; ability to integrate data from different sources, enabling real-time data monitoring and analysis, thus providing a broader view of circular processes to identify trends and inefficiencies), in line with the other dimensions.

Coming to the socio-business pillars, we note, first of all, in the **PEOPLE** pillar Cobat's strong inclination towards C.E. In fact, we have the highest scores (5-EXPLOITED) in all the dimensions answered except one (4-INTEGRATED). The starting AS-IS level is already very high (average 4-INTEGRATED, indicating the presence of a Strategic Business Unit dedicated to the Circular Economy, with the task of supporting all other functions or SBUs; the presence of circular activities such as, e.g., material collection and recycling programs and product reuse; a defined roadmap for the acquisition and development of Circular Economy skills; sustainable communication and marketing, circular finance, innovative thinking; and Circular Economy Ethics as part of business processes. ETB reaches maximum levels: Circular Economy is at the heart of corporate culture; all employees are trained and participate in continuous improvement processes; full commitment to sustainable investments; participation in setting industry standards for sustainable products and promoting consumer education and awareness: defined roadmap for acquisition and development of Circular Economy skills; staff training programs; systems for evaluating operator skills and mechanisms for reward and career development; sustainable communication and marketing, circular finance, innovative thinking.

The responses of the PEOPLE pillar are confirmed and reinforced by those of the

PARTNERSHIP pillar. In this pillar, too, the AS-IS situation is, on average, close to 4-INTEGRATED, and aspires to reach the 5-EXPLOITED level in 3 out of 6 dimensions.
The strongest relationship is with Suppliers, already at level 5-EXPLOITED at the beginning of the project; strategic partnerships with suppliers are systematic and encompass the entire product life cycle, with commitment to continuous improvement in circularity.
The other two dimensions where an ETB = 5.EXPLOITED is expected to be achieved are Customers and Research & Innovation Centers; in both cases we start from AS-IS 4.INTEGRATED (collaboration in R&I projects and engagement with customers in co-creating products with Circular Economy principles in mind), while at the 5-EXPLOITED level we would have a more systematic and partnership approach.
Relationships with IT Providers are already advanced (4-INTEGRATED, data exchange platforms endowed with Data Analytics and AI capabilities), and those with Training and Education Centers would be strengthened (from 3-DEFINED to 4-INTEGRATED, with a more planned approach).

Also in KPIs (**PERFORMANCE**) Cobat expects to achieve remarkable levels. The Operations, Economics and Social indicators are diagnostic; the Environmental KPIs will progress from an AS-IS 4-INTEGRATED (predictive) to 5-EXPLOITED (prescriptive - future oriented), consistent with the scope of the project and in line with the overall trend; in the Product-Service System, Environmental LCA functionality is expected to be added (4-INTEGRATED) and in the Supply Chain full exploitation is expected to be achieved (5-EXPLOITED) by extending monitoring to the physical, economic and sustainability performances.

6.2.2 Battery - Raeeman

The results of the compilation from Raeeman are summised in Figure 27.

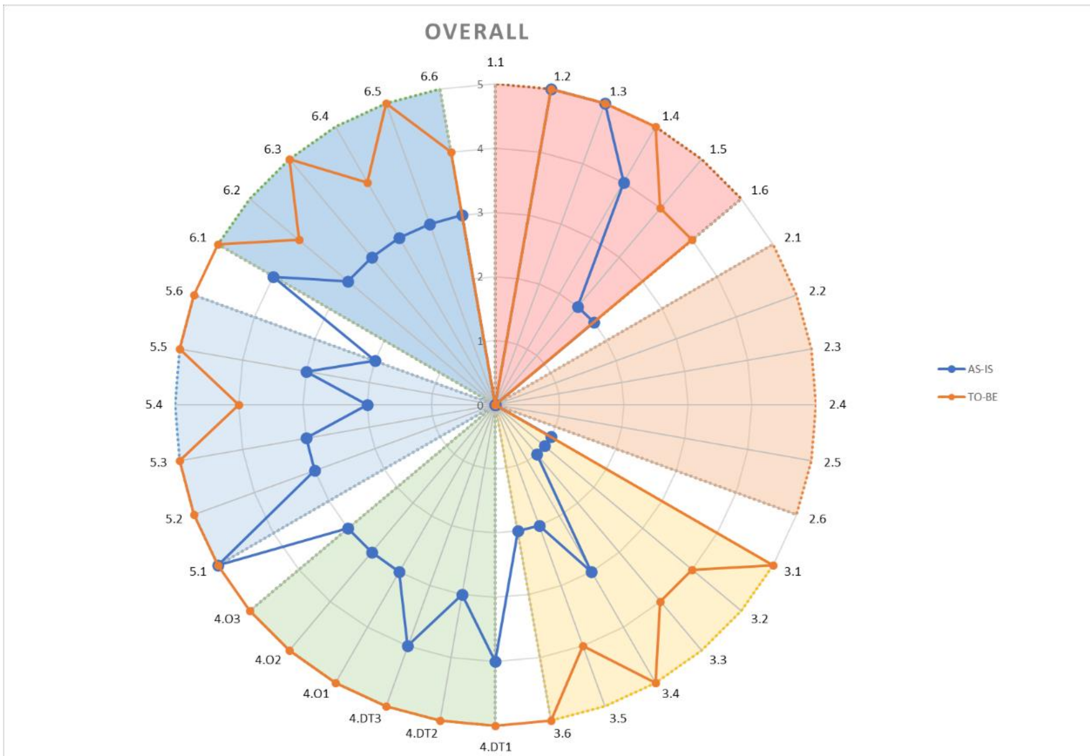

Figure 27 – Battery – Raeeman Overall Results

In this case we note some similarities and some differences with what we have observed so far.
Among the similarities, we see that the Socio-Business pillars exhibit the same pattern seen so far: high AS-IS levels (around 3-DEFINED) and consistent expected progress (ETB well above 4-INTEGRATED).
Among the differences, we see that the technical pillars follow different patterns: PRODUCT is similar to the Socio-Business pillars (high AS-IS and major progress); PROCESS was rated Not Applicable; PLATFORM, on the other hand, follows the "traditional" pattern, with not high AS-IS levels that, however, realign with the others in the ETB.

	AS-IS	Exp. TO-BE	Gap
PRODUCT	3,6	4,6	1,0
PROCESS			
PLATFORM	1,7	4,5	2,8
PEOPLE	3,3	5,0	1,7
PARTNERSHIP	3,0	4,8	1,8
PERFORMANCE	3,2	4,5	1,3

Table 3 - Battery – Raeeman Avg. Results in the pillars

In the **PRODUCT** pillar, the Raw Materials and End-of-Life dimensions are rated 5-EXPLOITED, both as AS-IS and ETB; in these areas Raeeman is already doing very well and is at the highest level; resource use is optimized, tracked, and transparent; there is activity on the EPR fronts; there is an established system in place for reuse, repair, remanufacturing, and reconditioning of products; and possible collaborations with recycling facilities and energy recovery programs.
Integration between PLM and DPP (dimension 1.4) was already well advanced at the beginning of the project (4-INTEGRATED), and there is a goal to achieve the highest levels of utilization at the end (ETB = 5-EXPLOITED), so PLM and DPP are fully integrated, thus ensuring end-to-end visibility and traceability in real time.
The two BMs dimensions were assessed consistently; both start from AS-IS 2-MANAGED levels (pilot projects related to circular business models, enabled by digital systems) and have the goal of achieving an ETB = 4-INTEGRATED: circular business models (like PaaS, leasing or take-back programs) shall be tentatively fully established, re-designing the supply chain and rethinking products lifecycle to prioritize sustainability and resource efficiency, and will be enabled by digital systems implementing an interoperable data exchange framework, potentially involving all possible circular operators.

The **PROCESS** pillar was rated Not Applicable to the pilot.

The **PLATFORM** pillar responses show where Raeeman's effort is being focused in this project. They start with AS-IS values between 1-INITIAL and 2-MANAGED (average AS-IS = 1.7) and the goal is to achieve ETBs of 4-INTEGRATED or 5-EXPLOITED in all 6 dimensions, with an average ETB of 4.5. The gap closed would come to be 2.8 points, one of the highest progress in the entire survey.
DPP, DT and AAS will be developed, uniformly, from a 1-INITIAL value to 5-EXPLOITED values for DPP and 4-INTEGRATED for DT and AAS. Rating 1-INITIAL indicates the

absence of these three instruments at the beginning of the project. The DPP will be developed to full exploitation (a DPP integrated with Blockchain and Decentralized PLM, taking care also of. standardization, interoperability and use of open data), as is in the main goals of the Circular TwAIn Project; DT and AAS will be developed up to level 4-INTEGRATED, where Digital Twins are integrated with IoT and endowed with AI and learning capabilities that allow detailed simulations and optimization of the resources and of product lifecycle, whereas AAS shall be integrated across the organization with the Internet of Things (IoT) and artificial intelligence, in applications that may encompass predictive maintenance, demand forecasting and resource planning.

As in the other pilots, Raeeman's strong leaning toward C.E. is demonstrated by responses to the **PEOPLE** pillar. The AS-IS is 4-INTEGRATED in the dimensions Strategy and Implementation (Circular Economy has a key role in the corporate strategy and activities include material collection and recycling programs and product reuse, in cooperation with SC tiers; results are monitored with dedicated KPIs), 3-DEFINED in the 4 dimensions Culture and Organization, Staff and Expertise, Staff Skills, Ethics.
In all the six dimensions of this pillar it is intended to achieve the highest ETB scores, 5-EXPLOITED, indicating:

- Strategy: C.E. will make the main revenue streams
- Culture and Organization: C.E. as the core of the corporate culture; all employees are trained
- Implementation: full commitment to sustainable investments and participation in setting industry standards for sustainable products
- Staff and Expertise: roadmap for the acquisition and development of C.E. skills
- Skills: staff training programmes; staff assessing and rewarding mechanisms
- full adhesion to C.E. Ethics

All the same as to the **PARTNERSHIP**, responses that confirm Raeeman's commitment to the development of circular practices. The highest score is in partnerships with R&I Institutes (5-EXPLOITED: systematic participation in common R&I programs, with technology transfer partnerships).
Relationships with Training & Education Centers, IT Solution Providers, and Customers will be developed from an AS-IS 3-DEFINED to ETB 5-EXPLOITED: learning programs and collaborations with educational institutions; dynamic engagement with IT vendors, seeking opportunities for mutual growth; customers seen as partners in ongoing engagement.
Supplier relationships start at a lower AS-IS, 2-MANAGED, but will also be well developed to an ETB 4-Integration relationship: strategic partnerships in which suppliers are seen as key contributors to circular economy goals, such as: joint product development, closed-loop systems, and collaborative efforts.
Finally, there is significant progress in the dimension of industry agreements, aiming to reach a 5-EXPLOITED level, where formal industry agreements are in place, establishing common rules and voluntary B2B data sharing schemes that encompass all stages of the data lifecycle and cover all elements needed to develop an industrial data space.

The answers given in the **PERFORMANCE** pillar; finally, show how Raeeman aspires to achieve high levels of monitoring and control of its activities.
The Operations KPIs are at AS-IS predictive (4-INTEGRATED) levels and will be

supplemented with prescriptive skills.

The indicators of the Economics move from diagnostic (3-DEFINED) to predictive (4-INTEGRATED).

The KPIs of the Environmental and Product-Service Lifecycle dimensions, which are the most relevant to this Circular Economy project, expect to see the greatest progress (2 levels), moving from 3-DEFINED to 5-EXPLOITED. In the case of Environmental indicators this would mean developing prescriptive indicators, while in PS Lifecycle KPIs lifecycle assessment towards Circular Economy would be added.

Social KPIs will progress from 3-DEFINED (diagnostic) to 4-INTEGRATED (predictive).

Supply Chain KPIs from 3-DEFINED (physical and economic measures in suppliers evaluation) to 4-INTEGRATED (also measuring supplier sustainability attitude).

6.2.3 WEEE - Revertia

The compilation of the survey by the WEEE-Revertia pilot, the results of which we report in Figure 28 and Table 4, is very comprehensive and well done, and enriched with useful explanatory notes.

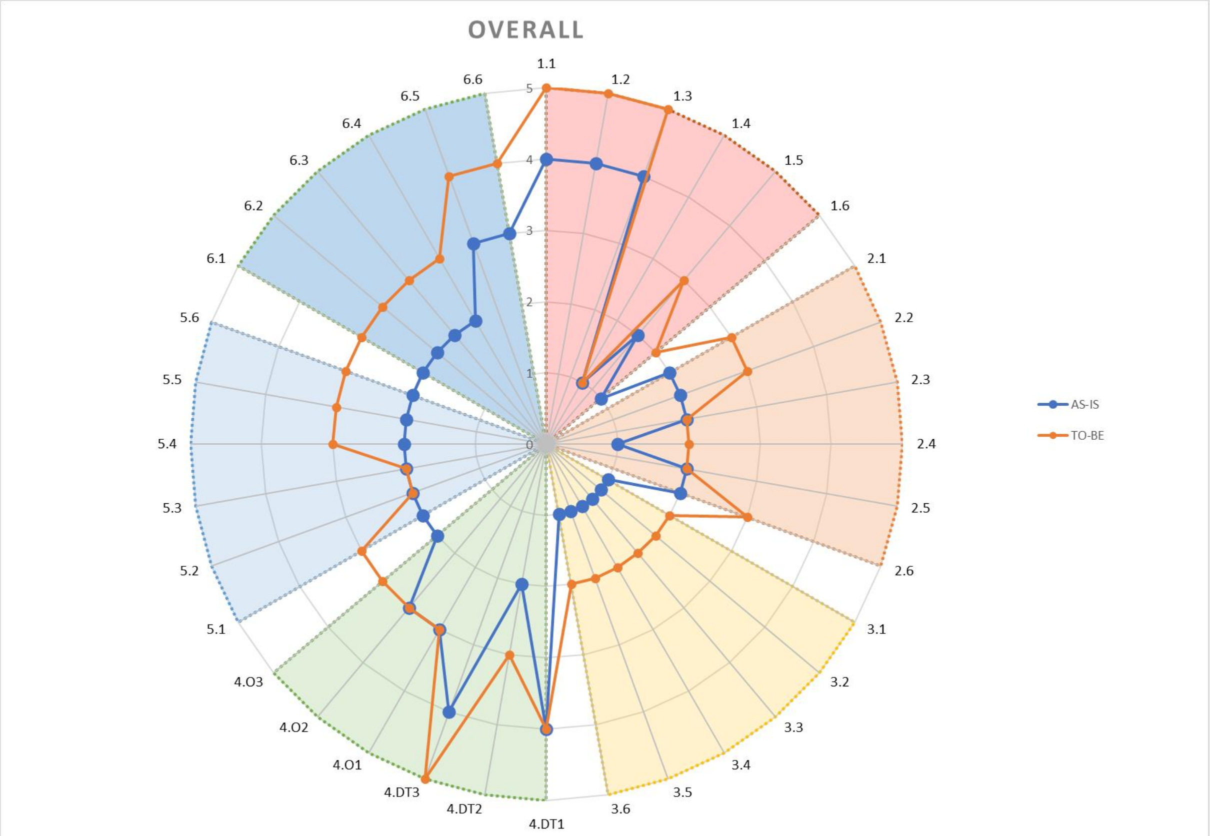

Figure 28 – WEEE – Revertia Overall Results

In this pilot, we observe a slightly different pattern from those in the Battery, and also from the overall pattern. Again, the Socio-Business pillars have higher AS-IS scores than the technical pillars, but the difference is less pronounced, and is actually only present in the PEOPLE. The gaps filled are about uniform across all pillars, averaging 1 point or less, so in the ETB the differences we had in the AS-IS are preserved. Overall, then, this pilot is presented with the goal of achieving general improvement in all areas examined, rather than focusing effort on only a few.

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	AS-IS	Exp. TO-BE	Gap
PRODUCT	2,7	3,5	0,8
PROCESS	1,8	2,5	0,7
PLATFORM	1,0	2,0	1,0
PEOPLE	3,0	3,5	0,5
PARTNERSHIP	2,0	2,7	0,7
PERFORMANCE	2,3	3,3	1,0

Table 4 - WEEE – Revertia Avg. Results in the pillars

The **PRODUCT** pillar was compiled taking into account that Revertia is an electrical and electronic equipment management company and a specialist in equipment reconditioning; thus, in this aspect it closes the circularity loop by giving IT equipment a second life through its processes.
Therefore, two distinct groups of responses are evident in this pillar.
The first three dimensions (Product D&E, Raw Materials and EOL) have high AS-IS scores (4-INTEGRATED) and are expected to achieve ETB scores 5-EXPLOITED: products will have to be designed according to circularity principles, with a closed-loop approach, and subjected to LCA to ensure minimal environmental impact; resource use will have to be optimized, tracked, transparent, and subject to continuous improvement; there will be a system for reuse, repair, remanufacturing, and refurbishment of products, and collaborations with recycling facilities and energy recovery programs.
While in the dimensions directly related to product there will be maximum exploitation, there are no plans, however, to develop discourses in the sense of developing and integrating PLM and DPP (1-INITIAL).
Regarding the new Business Models, at the end of the project it is expected that it will be possible to have in place circular business models, like PaaS, leasing or take-back programs (3-DEFINED), which at the moment are only in the pilot phase (2-MANAGED), while it is not yet clear to what extent the use of data will be able to enable the new BM, so in the sixth dimension there is limited progress, from 1-INITIAL to 2-MANAGED.

In the **PROCESS** category, as well as in the product category, Revertia is a WEEE management company that prioritises the reconditioning of computer equipment coming from different entities (banks, administration, textile, food). Therefore, it is intrinsically associated with the reintroduction into the market flow of equipment (PCs, laptops, screens, others) through the reconditioning granted, the lifetime of which is extended.
In view of this, the process benefits brought by the Circular TwAIn Project will be limited to some improvements in some operational areas, but not very big steps forward are expected.
The functions of Design & Engineering, Production and EOL Management, and SC Management will move from an AS-IS = 2-MANAGED to an ETB = 3. DEFINED; this indicates the presence of some life-cycle and eco-design thinking in product development, taking into account maintainability, durability, and modularity; that the importance of product life-cycle management is recognized and connections between manufacturing processes, product end-of-life management, and product rework will therefore be implemented, probably with reverse logistics programs initiated; and that raw material suppliers will be evaluated based on their sustainability practices and resource efficiency.
Quality Control Management and Reverse Logistics Management functions are already at

the AS-IS 2-MANAGED level (the QCS is able to manage material selection and production processes from a Circular Economy perspective, and there is a basic system for recording returns and inventory management of products returned for repair or warranty) and will remain so.
Finally, after-sales services will be enhanced from a 1-INITIAL level to a 2-MANAGED ETB level (provision of spare parts and after-sales services to customers; basic troubleshooting and/or end-of-life instructions; basic mechanisms for tracking and collecting product usage data).

In the case of **PLATFORM**, it must be distinguished that Revertia's process currently has no sensors and does not collect data in real time; there are conventional computer tools (software for recording operations or for warehouse management) that allow data to be recorded, but they rely on staff to perform this task.
The responses given reflect this situation. Uniform improvement is expected in all dimensions, all of which will move from a 1-INITIAL to an ETB 2-MANAGED level, so:

- DPP will be initiated for some products
- the adoption of Digital Twins will be initiated in order to optimise some processes
- AAS implementation will begin
- a Data Space with basic functionalities will be put in place
- they will implement an Industrial Data Platform as a basic repository to collect and store circular process data
- analytics techniques will be used for basic functionalities.

The **PEOPLE** pillar highlights a robust corporate structure that is already in place and ready to embrace and manage C.E. innovations, as seen for the other pilots as well. At Revertia, staff are involved in and dedicated to the Circular Economy, as it is Revertia's core business; Revertia converts e-waste into products or, failing that (for equipment not amenable to reconditioning), contacts suppliers who recycle it as much as possible, either through the manufacture of new products or energy recovery.
That said, it is not surprising that the highest ratings in this pillar belong to the Strategy and Implementation dimensions. Strategy has a 4-INTEGRATED rating, which remains unchanged in the ETB, indicating that Circular Economy plays a key role in Revertia's business strategy. Implementation will grow from an AS-IS 4-INTEGRATED (activities include programs to collect and recycle materials and reuse products, in collaboration with Supply Chain partners; results are monitored with dedicated KPIs) to an ETB 5-EXPLOITED, with participation also in setting industry standards for sustainable products and promoting consumer education and awareness.
The other dimensions examined will reach or maintain level 3-DEFINED: a set of roles and tasks will be defined among staff with specific Circular Economy skills, aimed at implementing current lines of development; the professional skills needed for Revertia projects are currently identified and acquired, and staff training programs and/or skills evaluation systems are in place; staff possess skills such as materials knowledge and management, use of sustainable technologies, and eco-design; and Circular Economy Ethics will be systematically incorporated as part of processes.

Responses from the **PARTNERSHIP** pillar also show propensity for improvement through external collaborations. For example, Revertia has entered into agreements with universities for the induction of profiles in the company who have obtained a master's degree related to sustainability and the Circular Economy; on the other hand, it promotes at its customers the inclusion of waste collection campaigns with its employees in order to provide a second life to the equipment supplied through reconditioning.

AS-IS levels are uniformly 2-MANAGED in all 6 survey dimensions.

This starting level is improved to 3-DEFINED in the dimensions R&I Institutions (active participation in joint research and innovation projects), Suppliers (collaboration: suppliers are selected and engaged according to circularity principles), Customers (collaborative approach: customer feedback is actively sought) and Industry Agreements (supportive relationships and initial formal activities are in place to foster data sharing schemes and support the development and operation of data spaces), while it is expected to remain unchanged in the Training & Education (only occasional skills assessment and training programs for a few C.E. roles) and IT Solution Providers (IT providers support with SW solutions).

When it comes to performance indicators (**PERFORMANCE**), Revertia envisions a uniform improvement of the first four (Operations, Economics, Environmental, Social) which will all move from a descriptive (2-MANAGED) to a diagnostic (3-DEFINED) approach.

KPIs assessing product life cycle will move from a 3-DEFINED AS-IS (LCC toward recycling, de-manufacturing KPIs) to a 4-INTEGRATED ETB (LCC + environmental LCA toward circular economy).

Supply chain performance indicators will move from an AS-IS 3-DEFINED (assessment of physical and economic performance) to an ETB 4-INTEGRATED (supplier sustainability performance will also be assessed).

6.2.4 Petro - Socar

The last pilot examined is Petro - Socar (Figure 29 and Table 5).

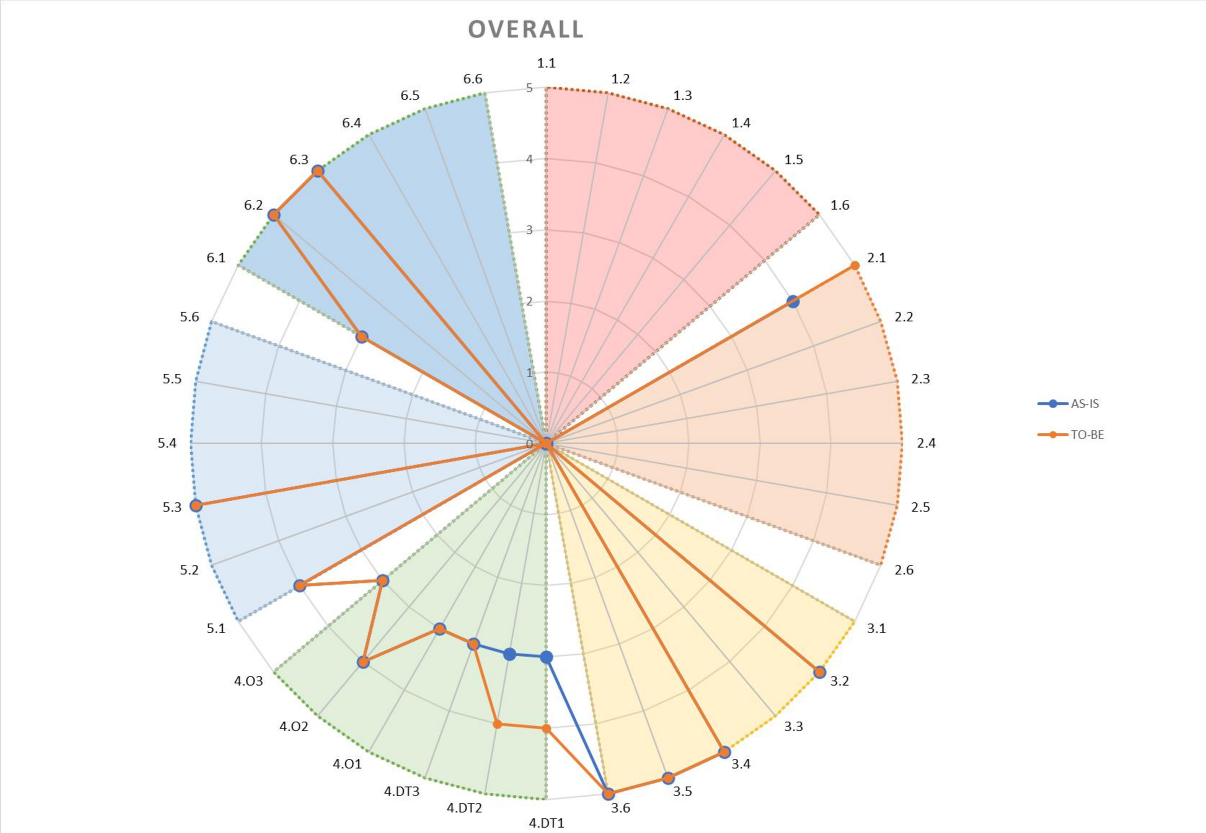

Figure 29 – Petro – Socar Overall Results

As it can be seen, only part of the questions was answered, as most of the questions were deemed not suitable for an Oil & Gas company.

	AS-IS	Exp. TO-BE	Gap
PRODUCT			
PROCESS	4,0	5,0	1,0
PLATFORM	5,0	5,0	0,0
PEOPLE	3,2	3,5	0,3
PARTNERSHIP	4,5	4,5	0,0
PERFORMANCE	4,3	4,3	0,0

Table 5 - Petro – Socar Avg. Results in the pillars

The **PRODUCT** pillar was rated Not Applicable.

In the **PROCESS** pillar, only the Design & Engineering question was rated Applicable, and will see an advancement from 4-INTEGRATED (life cycle thinking is incorporated from the design stage, including circularity elements such as modularity, durability, maintainability, reparability and recyclability; the adoption of Digital Twins is being developed) to 5-EXPLOITED (products are designed considering the entire life cycle, from sustainable sourcing of materials to end-of-life management; elements of circularity such as modularity, durability, maintainability, reparability, and recyclability are systematically incorporated; Digital Twins are adopted to help optimize performance).
The other 5 dimensions were considered Not applicable.

In **PLATFORM**, 4 out of 6 questions were answered: Digital Twin, Data Spaces, Industrial Data Platform, and Data Analytics. All had 5-EXPLOITED ratings in both the AS-IS and ETB, namely:

- Digital Twins are adopted comprehensively and strategically, supported by advanced AI models endowed of Machine Learning, capable of handling complex scenarios, from design and production to end-of-life management;
- Data Space integrates data from different sources and incorporates data processing and analysis capabilities, with advanced simulation and machine learning capabilities; it incorporates the concepts of Interoperability and Supply Chain transparency and can also support lifecycle traceability;
- an Industrial Data Platform has been successfully integrated across the entire organisation's Circular Economy practices; it includes features such as advanced simulations, machine learning, full product lifecycle tracking and advanced Digital Twin management;
- Data Analytics are used for forecast and prediction AI/Machine Learning models for instantiating “what-if analysis”; dynamic behavioural simulations based on models and on user-supervised “what-if” scenario exploration & validation are possible.

The other two dimensions, DPP and AAS, were rated as Not Applicable to this pilot.

PEOPLE shows the same trend as the other pillars, indicating a predisposition of the Socar organization toward C.E. practices. In fact, in this pillar, all dimensions were considered applicable.
The first two dimensions, Strategy and Organization & Culture, will see an improvement over the course of the project, from 3-DEFINED to 4-INTEGRATED; indicating that the Circular Economy will play a key role in Socar's business strategy and that a dedicated Circular Economy function or SBU will be established to support all other functions or SBUs.
The Implementation and Staff & Expertise dimensions will maintain the AS-IS 3-DEFINED value, corresponding to the implementation of actions to increase process efficiency and reduce waste of materials, energy, or resources, and the ability to identify and acquire professionals needed for Socar's projects.
Skills, which are rated 4-INTEGRATED in the AS-IS, will remain the same (data analysis skills, SC management, systemic thinking).
C.E. ethics are assessed as 3-DEFINED (circular economy ethics and its value principle of sustainable development are systematically part of Socar's processes).

PARTNERSHIP have been rated only with reference to R&I Institutions (4-INTEGRATED; collaboration in R&I projects involving data collection, data sharing and data analytics, to better understand C.E. patterns and impacts) and IT Solution Providers (5-EXPLOITED; engagement with IT providers is dynamic and seeks opportunities for mutual growth, ensuring that data plays a pivotal role in the commitment to sustainable practices and circular economic principle).
The other dimensions (Training & Education, Suppliers, Customers, Industrial Agreements) have been considered Not Applicable to this pilot.

In the **PERFORMANCE** pillar they have been rated the first three dimensions: Operational, Economics and Environmental.
The first one, Operational, sticks to its AS-IS value 3-DEFINED (diagnostic approach).

The other two (Economics and Environmental) have already the highest ranking, 5-EXPLOITED, corresponding to a system of Prescriptive KPIs that supports decision making, boosting optimization and simulation to find the best course of action.
The next three dimensions (Social, PS Lifecycle, Supply Chain) have been considered Not Applicable to this pilot.

7 Lessons learnt and conclusions

7.1 Lessons learnt

The lessons learnt invest multiple aspects of this work.

First of all, there is a level of learning for the POLIMI interviewers themselves, who, thanks to the close relationships maintained with compilers and pilot leaders, have been able to deepen their knowledge of concrete applications of Circular Economy principles in SMEs. The knowledge thus developed enters the personal knowledge pool, and can profitably be redeployed in other work, either within other European projects or in the professional field as a whole.

There is a level of learning for interviewees. The interviewed companies had to put themselves on the line of explaining in detail to their colleagues the development and perspectives of the pilots. One line of exchange was, e.g., the impact of the experiment on the business processes, as analysed by the CE6Ps, by which SMEs were requested to examine in depth, as part of a fruitful comparison, the impact of the pilot on the respective organizations, dimension by dimension.
The lesson learned, in this case, concerns the usefulness of additional analysis tools to capture aspects that had not been planned.

Then there is a broader level of lesson learnt, which concerns dissemination: the compilations and interviews were preceded by several calls among the members of the consortium to set-up the assessment tool; this created additional dissemination moments above the institutional ones already planned in other work packages.
This approach determined the creation of benchmarks and increased the awareness of the utility of the experiments in all participants, and strengthened mutual understanding among project participants.
The aggregated results illustrated in this deliverable also strongly contributed to greater awareness and dissemination; the comparison with other pilots enabled pilot leaders to improve their vision and better focus actions and efforts in the experiment.

Finally, there is a final, even broader level of lessons learnt, which is also the main one: the work done in recent months to develop a version of the 6Ps dedicated to the Circular Economy has demonstrated the great versatility and practicality of this tool. Tailored versions of the 6Ps Digital Transformation Models for specific instantiations, e.g., focused on the use of Data/AI, or on specific industry sectors such as Process or Energy, had already been prepared in the past, but this time, for the first time, the tool was completely revisited. The result obtained was satisfactory because it showed that it could describe well the characteristics of a pilot or enterprise involved in C.E. projects.

7.2 Next steps

Task 2.4 of WP2 states that two iterations will take place, one at M18, where responses are given according to expectations from the pilot, and a second one at M36, at the end of the project, when the results will be actual.
The second iteration of the experiment will be run after the experiments are completed, so as to compare the expected / planned outcome with the actual ones.

This is due in month M36, and will be the subject of deliverable D2.6.
The second iteration will be very useful to:

- measure the real impact of the pilots on the companies; where the progress was, why, how it was achieved;
- assess the vision and planning capacity of the pilot leaders: goals achieved, deviations from expected results, possible corrective actions;
- the next iteration of the CE6Ps will thus result in not only an analysis of the type already seen in this deliverable, but, in addition to it, an analysis of which pilots performed best in terms of actual results vs. expected results, trying to analyse and explain the reasons in relation to the pilot typicalities;
- further improving the development and use of the 6Ps model, including devising new applications of it.

7.3 Conclusions and future outlook

The application of the CE6Ps to the pilots in this 1st iteration has proven very fruitful, as it was expected when the idea of introducing a dedicated task for this activity was first considered.

First of all, the dissemination methodology adopted, based on presentations, exchange of information in group meetings, and interviews, allowed for a great circulation of ideas, which added its effect to what was already provided in the other areas of the project in enriching the technical and practical knowledge of the participants, as well as the team spirit of the project.

SMEs were able to analyze and evaluate the conduct and expected results of their pilots from a new point of view, based on a defined and uniform method.

Another positive spillover is that the insights gained in the meeting and the comparison with other pilots are helping to improve the pilot leaders' focus, in preparation to the second iteration of the CE6Ps.

While the CE6Ps provided experiments with an analysis tool from a different perspective, the experiments were a test bench for the validation of the tool. Compilations allowed the use of CE6Ps to be refined, with a view to future applications in this and in other projects. We could thus speak of cross-validation: the CE6Ps provided the pilots with a validation tool, and the pilots validated the CE6Ps tool and allowed its use to be refined.

The second iteration will be a great opportunity to understand how much the lessons learnt from this first iteration were really learned, how much put into practice, through what levers and by whom and in what way.

All this will be the subject of deliverable D2.6, scheduled for M36.

ANNEX I – "Circular Economy 6Ps" questionnaire

PRODUCT

1. PRODUCT DESIGN & ENGINEERING
How does your company incorporate Circular Economy principles in the design & engineering of its new products?
1. INITIAL: We do not incorporate concepts of Circular Economy in our design and engineering processes.
2. MANAGED: In our design & engineering process we take into account concepts of durability, sustainability or recycling. Occasional efforts to use sustainable materials or optimize energy efficiency are made.
3. DEFINED: Principles of durability, energy efficiency, sustainability and material recyclability are systematically part of our design & engineering processes.
4. INTEGRATED: Our products are designed with a view to re-use, re-manufacturing, de-manufacturing, disassembly, re-cycling, and with reference to user requirements and industry standards.
5. EXPLOITED: Our products are designed according to circularity principles, with a closed-loop approach. Every product undergoes LCA (Life Cycle Assessment) to ensure minimal environmental impact over its life cycle. We take part in setting industry standards for sustainable product design and in promoting consumers education and awareness.

1.2 RAW MATERIALS
How advanced is your company's approach to raw materials management, so as to effectively combine the utilization of primary and recycled raw materials?
1. INITIAL: We follow a traditional linear model; we are mainly focused on the optimization in costs and use of resources.
2. MANAGED: We are committed to waste reduction and to the use of scraps, co-products and by-products.
3. DEFINED: Our company has established guidelines for the use of raw materials (such as waste reduction, use of scraps, use of co-products and of by-products); we adhere to the principles of Extended Producer Responsibility (EPR).
4. INTEGRATED: We have guidelines to optimize the use of primary and recycled raw materials; we have adopted Circular Economy principles into our raw material management, such as traceability, transparency, verification systems and Extended Producer Responsibility (EPR).
5. EXPLOITED: Our company is a leader in Circular Economy-driven raw material management. The use of resources is optimized, tracked, transparent and subject to continuous improvement. We are also active on the fronts of EPR and consumer awareness.

1.3 END-OF-LIFE
How does your company currently manage the end-of-life of its products in the context of a Circular Economy?
1. INITIAL: We do not have any specific process in place to manage the end-of-life of our products.
2. MANAGED: We can offer re-use, repair and/or refurbishment services, so as to extend product's lifecycle.
3. DEFINED: We actively promote the re-use, repair, refurbishment, re-manufacturing, recycling for a significant portion of our products.
4. INTEGRATED: We have an established system for product re-use, repair, re-manufacturing and refurbishment; we have in place collaborations with recycling facilities and energy recovery programs.
5. EXPLOITED: We have an established system for product re-use, repair, re-manufacturing and refurbishment; we have in place collaborations with recycling facilities and energy recovery programs.
We have take-back programs for de-manufacturing and re-purposing.

1.4 PRODUCT LIFECYCLE MANAGEMENT AND DIGITAL PRODUCT PASSPORT
How effectively does your company handle the Product Lifecycle Management and the Digital Product Passport of its products, in connection among them?
1. INITIAL: There is no use of these tools.
2. MANAGED: We are implementing Product Lifecycle Management and/or Digital Product Passport; we are making attempts to integrate product data throughout the product life-cycle, to implement product traceability and end-to-end visibility.
3. DEFINED: Data integration between Product Lifecycle Management and Digital Product Passport is in progress, leading to improved end-to-end visibility and product traceability.
4. INTEGRATED: We handle Product Lifecycle Management and Digital Product Passport in a connected manner; data integration is well-established, providing comprehensive end-to-end visibility and products traceability.
5. EXPLOITED: We integrate Product Lifecycle Management and Digital Product Passport seamlessly, so ensuring real-time end-to-end visibility and traceability.

1.5 NEW BUSINESS MODELS ENABLED BY THE CIRCULAR ECONOMY
To what extent is your company exploring new business models enabled by the Circular Economy?
1. INITIAL: Our company has not explored new business models enabled by the Circular Economy. We are currently operating under traditional business models.
2. MANAGED: We have some pilot projects related to circular business models.

3. DEFINED: Circular business models, like PaaS (Product-as-a-Service), leasing or take-back programs are being implemented for specific product lines or customer segments.
4. INTEGRATED: Circular business models, like PaaS (Product-as-a-Service), leasing or take-back programs are fully established; we have re-designed our supply chain and rethought our products lifecycle to prioritize sustainability and resource efficiency.
5. EXPLOITED: Circular business models make our main revenue streams.

1.6 USE OF DATA TO ENABLE NEW BUSINESS MODELS
To what extent are your new Business Models data-driven in a Circular Economy perspective?
1. INITIAL: Our company has no circular business models; or, our new Circular Economy business are enabled without any data infrastructure.
2. MANAGED: New simple business models have been enabled by digital systems involving e.g. only specific system suppliers.
3. DEFINED: New business models have been enabled by digital systems managing one-to-one data exchanges; potentially, all possible circular operators (system suppliers, component suppliers, circular material suppliers…) could be involved.
4. INTEGRATED: New business models have been enabled by digital systems implementing an interoperable data exchange framework, which involves, potentially, all possible circular operators.
5. EXPLOITED: The circular supply chain is fully managed by an interoperable data exchange framework allowing to guarantee the data sovereignty and the complete visibility of the supply chain. The data exchange itself along the supply chain is recognised as a new business model since the data have a value managed by the digital framework.

PROCESS

2.1 DESIGN & ENGINEERING
How does your company approach Design & Engineering processes in the context of Circular Economy?
1. INITIAL: We do not incorporate concepts of Circular Economy in our design and engineering processes.
2. MANAGED: We prioritize waste reduction and use of sustainable materials.
3. DEFINED: We have established some lifecycle thinking and eco-design in our product development, taking into account maintainability, durability and modularity.
4. INTEGRATED: Lifecycle thinking is embedded from the design stage, including circularity elements like modularity, durability, maintainability, repairability and recyclability. The adoption of Digital Twins is being developed.
5. EXPLOITED: Products are designed considering their entire lifecycle, from sustainable material sourcing to end-of-life management. Circularity elements like modularity, durability, maintainability, repairability, recyclability are systematically integrated. Digital Twins are adopted to help optimize performances.

2.2 MANAGEMENT OF PRODUCTION AND END-OF-LIFE RE-PROCESSING
How effectively does your company manage the connections among production processes, product end-of-life management and product re-processing, in line with Circular Economy principles?
1. INITIAL: There is no coordination between these aspects.
2. MANAGED: Our company has started adopting some founding concepts like sustainable materials selection, traceability, standardization and modularity.
3. DEFINED: We recognize the importance of the product's lifecycle management. We have implemented connections among production processes, product end-of-life management and product re-processing. Reverse logistics and take-back programs have been initiated.
4. INTEGRATED: We integrate production processes, product end-of-life management and product re-processing, Reverse logistics and take-back programs are actively carried on.
5. EXPLOITED: We have an integrated approach to production processes, product end-of-life and product re-processing. We have established reverse logistics and take-back programs, and efficiently re-process materials through recycling and re-manufacturing. Digital tracking and traceability systems adopt Digital Product Passports.

2.3 QUALITY MANAGEMENT
How well does your company implement Quality management in a Circular Economy environment?
1. INITIAL: Our Quality Management System does not take into account aspects of Circular Economy.
2. MANAGED: We have implemented a Quality Control System to manage material selection and production processes in a Circular Economy perspective.
3. DEFINED: We manage raw materials according to certification and standardization criteria. We have Quality Control Systems extended to the Supply Chain.
4. INTEGRATED: Our quality management is integrated in our supply chain processes: products traceability, raw materials certification and standardization, end-of-life planning and feedback loops ensure the quality of our products.
5. EXPLOITED: Our quality management is integrated in our supply chain processes: products traceability, raw materials certification and standardization, end-of-life planning, feedback loops, supported by customer

engagement and R&D efforts, ensure the quality of our products and of their components.

2.4 AFTER-SALES SERVICES

How does your company manage the after-sales services to customers for monitoring and managing the life-cycle of its products?

1. INITIAL: We follow a traditional linear model: we can supply spare parts and/or offer product repairing and maintenance services to our customers, but we have no mechanisms for monitoring the product's life-cycle.
2. MANAGED: We supply spare parts and offer after-sales services to customers, such as basic troubleshooting, repair services and/or end-of-life instructions. We have basic tracking mechanisms and collection of product usage data.
3. DEFINED: Our company provides after-sales services to customers, including spare parts, repairs, troubleshooting and/or end-of-life instructions. Tracking mechanisms and collection of product usage data are in place and are used to identify opportunities of product up-grading and refurbishment.
4. INTEGRATED: Our company offers robust after-sales services to customers, including spare parts, repairs, troubleshooting and/or end-of-life instructions. Tracking mechanisms and collection of product usage data are used systematically to implement programs of product up-grading, refurbishment, trade-ins, take back or recycling. We are at an initial stage with Digital Twin and/or Digital Product Passport technologies.
5. EXPLOITED: Our company is a leader in Circular Economy-driven after-sales services and product lifecycle monitoring. Digital Twin technology and/or Digital Product Passport are in use, enabling tracking and access to information for the products.

2.5 REVERSE LOGISTICS MANAGEMENT

How well does your company manage reverse logistics processes in a Circular Economy environment?

1. INITIAL: We have not implemented activities of reverse logistics.
2. MANAGED: We have implemented a basic system for the registration of returns and stock management of products returned for repair or warranty.
3. DEFINED: We integrate data from different sources and use data analysis tools; thus, we have a greater understanding and more efficient management of reverse logistics operations.
4. INTEGRATED: We utilize reverse logistics for product repairing, returns, remanufacturing and recycling.
We use advanced data analysis to optimise routes and times. Transparency ensures that stakeholders in the supply chain have clear insights into the journey of products.
5. EXPLOITED: Our company fully integrates reverse logistics to establish a closed-loop system. We efficiently manage product returns, remanufacturing and recycling. Transparency and traceability are extended end-to-end, to foster consumer engagement. We have robots and automatic transport systems.

2.6 SUPPLY CHAIN MANAGEMENT

How does your company manage its Supply Chain within a Circular Economy environment?

1. INITIAL: Our products are designed to be durable and repairable.
2. MANAGED: We give preference to recycled, reusable or renewable materials. We offer services to extend product life, such as repair and maintenance.
3. DEFINED: Our products are designed according to Circular Economy principles like durability, reparability, modularity, recyclability. Raw materials suppliers are assessed based on their sustainability practices and resource efficiency.
4. INTEGRATED: We have in place collaboration with suppliers and with recycling facilities. We have established reverse logistics systems to manage product returns, repairs, remanufacturing and recycling, that allow us to optimize material flows and resource utilization.
5. EXPLOITED: We have in place collaborations with our SC tiers to develop closed-loop material flows; we are developing infrastructures for collecting and processing used products; we engage with consumers to facilitate products returns at the end of life.

PLATFORM

3.1 DIGITAL PRODUCT PASSPORT

To what extent is your company adopting Digital Product Passports for its products in a Circular Economy environment?

1. INITIAL: We are not adopting Digital Product Passports. We rely on traditional product documentation methods.
2. MANAGED: Our company has initiated the adoption of Digital Product Passports for some products, in order to provide traceability and product information through a centralized system.
3. DEFINED: We have established Digital Product Passports to enhance traceability and end-of-life management. Standardization, interoperability and use of open data formats are applied.
4. INTEGRATED: We have established Digital Product Passports to enhance traceability and end-of-life management. Standardization, interoperability and use of open data formats are applied. Encryption and access management are implemented.
5. EXPLOITED: Our company consistently adopts Digital Product Passports and integrates Blockchain and Decentralized PLM. Standardization, interoperability and use of open data formats are applied. Customized user interfaces maximize accessibility, and the architecture is scalable.

3.2 DIGITAL TWIN

To what extent and for what purposes is your company adopting Digital Twins in its Circular Economy processes?

1. INITIAL: We have not adopted Digital Twins.
2. MANAGED: We have started the adoption of Digital Twins for real-time product monitoring and simulations in order to optimise some processes.
3. DEFINED: Our company adopts Digital Twins, integrated with IoT, to optimize our approach to product lifecycle management, product design, predictive maintenance and forecasting.
4. INTEGRATED: Our company consistently adopts Digital Twins, integrated with IoT and endowed of AI and learning capabilities, that allow us detailed simulations and optimisation of the resources and of products lifecycles.
5. EXPLOITED: Our company is adopting Digital Twins comprehensively and strategically, supported by advanced AI models endowed of Machine Learning, capable of handling complex scenarios, from design and production to end-of-life management.

3.3 ASSET ADIMINISTRATION SHELL

To what extent and for what purposes is your company adopting Asset Administration Shells (AAS) in a Circular Economy environment?

1. INITIAL: No Asset Administration Shells are implemented in our company.

2-MANAGED: We have begun to implement AAS with basic information useful for cataloguing and organising assets (recyclable components, circular products), starting with interoperability and standardisation of basic data.

3-DEFINED: AAS is part of our practices. Data and metadata are standardized. The purpose is to provide real-time control of assets or processes (e.g. information on the condition and current location of assets during transport or use) and support resources optimisation and products lifecycles management.

4-INTEGRATED: We have integrated AAS across our organisation with the Internet of Things (IoT) and artificial intelligence, in applications such as predictive maintenance, demand forecasting and resource planning; we are able to simulate the behaviour of assets or circular resources in an advanced way.

5-EXPLOITED: We have integrated AAS across our entire organisation's Circular Economy initiatives. We have implemented or are in the process of evolving into a DPP and using it in connection with Digital Twins to support the introduction of Product-as-a-Service (PaaS) Models.

3.4 DATA SPACES

Which of the following best describes your company's adoption of Data Spaces in a Circular Economy environment?

1. INITIAL: The concept of Data Space is not in use in our company.
2. MANAGED: We have a Data Space with basic functionalities such as Data Privacy, Data Security and Regulatory Compliance. The Data Space serves mainly as a static repository.
3. DEFINED: Our Data Space integrates data from different sources within the circular processes (such as monitoring sensors, IoT devices and monitoring systems), enabling a real-time visualisation of the circular ecosystem.
4. INTEGRATED: The Data Space integrates data from different sources and incorporates data processing and analysis capabilities for the optimisation of circular processes. The concepts of Data Trust and Sovereignty have been integrated.
5. EXPLOITED: The Data Space integrates data from different sources and incorporates data processing and analysis capabilities, with advanced simulation and machine learning capabilities. It incorporates the concepts of Interoperability and Supply Chain transparency. It can also support lifecycle traceability.

3.5 INDUSTRIAL DATA PLATFORM

How is your company adopting an Industrial Data Platform in the context of a Circular Economy, and to what extent does this application involve the concept of Data Interoperability?

1. INITIAL: The concept of Industrial Data Platform is not in use in our company.
2. MANAGED: We use an Industrial Data Platform as a basic repository to collect and store circular process data, including simple databases for data storage and management, in communication with each other.
3. DEFINED: Our Industrial Data Platform has well-defined policies, standards, and procedures. It is able to integrate data from different sources, including sensors, IoT devices and databases, enabling real-time monitoring and analysis of data, thus providing a broader view of circular processes to identify trends and inefficiencies.
4. INTEGRATED: Our Industrial Data Platform has a robust approach to data interoperability, enabling optimisation of circular processes and advanced functionalities such as the management of the supply chain and a marketplace for secondary materials.
5. EXPLOITED: We have successfully integrated the Industrial Data Platform across our entire organisation's Circular Economy practices. It includes features such as advanced simulations, machine learning, full product lifecycle tracking and advanced Digital Twin management.

3.6 DATA ANALYTICS

To what extent is your company able to manage heterogeneous data coming from different sources (both internal and external) and exploit it for decision-making purposes?

1. INITIAL: No analytics functionality.
2. MANAGED: Analytics techniques are used to filter and visualise data sets.

3. DEFINED: Forecast/prediction models for instantiating “what-if analysis” are possible, relying on data ingestion and data storage.
4. INTEGRATED: Forecast/prediction AI/Machine Learning models for instantiating “what-if analysis” are a common practice and rely on data ingestion and data storage; dynamic behavioural simulations & validation are possible.
5. EXPLOITED: Forecast/prediction AI/Machine Learning models for instantiating “what-if analysis” are a common practice and rely on data ingestion and data storage; dynamic behavioural simulations based on models and on user-supervised “what-if” scenario exploration & validation are possible.

PEOPLE

4.1 CIRCULAR ECONOMY STRATEGY
What role does the Circular Economy play in your business strategy?
1. INITIAL: Circular Economy is not strategic for our company.
2. MANAGED: We are in the process to study the market to identify opportunities.
3. DEFINED: We are developing a strategic stream focused on Circular Economy in our corporate strategy.
4. INTEGRATED: Circular Economy has a key role in our corporate strategy.
5. EXPLOITED: Circular Economy is our mission and make our main revenue streams.

4.2 CIRCULAR ECONOMY CULTURE AND ORGANIZATION
Does your organisation have internal roles and competencies related to the Circular Economy? Does it promote employee participation in the development of circular products and processes?
1. INITIAL: Our company culture is not oriented to Circular Economy; no internal roles or competencies are currently defined.
2. MANAGED: Our management is getting interested and updated on C.E. topics; we have staff with certain competences, but no specific roles or tasks have been specified or identified.
3. DEFINED: We have defined a number of roles and tasks among the staff that have specific Circular Economy skills, aimed at implementing the current lines of development; we are conducting training to improve this knowledge.
4. INTEGRATED: We have a function or a Strategic Business Unit dedicated to the Circular Economy, with the task of supporting all other functions or SBUs. The Circular Economy culture is spreading in the company, also thanks to employees training.
5. EXPLOITED: The Circular Economy is the core of our corporate culture and our organisation is fully structured for it. All employees are trained and participate in continuous improvement processes.

4.3 CIRCULAR ECONOMY IMPLEMENTATION
What Circular Economy initiatives have already been implemented in your organisation?
1. INITIAL: We have no initiatives within the Circular Economy.
2. MANAGED: We started an assessment of the company's processes and products to identify opportunities for improvement in a Circular Economy perspective, also involving the staff.
3. DEFINED: Actions have been implemented to increase process efficiency and reduce waste of materials, energy or resources; we have initiated R&D programmes for more environmentally friendly products.
4. INTEGRATED: Our activities include material collection and recycling programmes and product reuse, in cooperation with partners of our Supply Chain; results are monitored with dedicated KPIs.
5. EXPLOITED: We are fully committed to sustainable investments; we participate in setting industry standards for sustainable products and in promoting consumer education and awareness.

4.4 STAFF AND EXPERTISE
How do you recruit, develop and retain Circular Economy skills in your organisation?
1. INITIAL: We have no initiatives in this regard.
2. MANAGED: The expertise is provided to us exclusively by external technology providers and consultants.
3. DEFINED: We identify and acquire the professionals needed for our projects; we have staff training programmes and/or competence evaluation systems.
4. INTEGRATED: We have defined a roadmap for the acquisition and development of Circular Economy skills, consistent with our strategic plans. We have staff training programmes, defined according to profiles.
5. EXPLOITED: We have defined a roadmap for the acquisition and development of Circular Economy skills, consistent with our strategic plans. We have staff training programmes, defined according to profiles. We have systems for assessing the skills of operators and reward and career development mechanisms, linked to performance evaluations and skills growth.

4.5 SKILLS
In the field of Circular Economy, what are the most advanced achievements among your staff?
1. INITIAL: Our staff does not have specific expertise on the Circular Economy.
2. MANAGED: We are getting acquainted with regulations and with the implementation of repair and maintenance programmes.
3. DEFINED: Knowledge and management of materials, use of sustainable technologies, eco-design.
4. INTEGRATED: Data analysis, Supply Chain management, systems thinking.
5. EXPLOITED: Sustainable communication and marketing, circular finance, innovative thinking.

4.6 CIRCULAR ECONOMY ETHICS

Does your organisation take into account the Circular Economy Ethics and its surrounding value principle of sustainable development?

1. INITIAL: We do not take into account the Circular Economy Ethics in our processes.
2. MANAGED: We are committed to follow the principles of the Circular Economy Ethics and occasional efforts are made to follow the value principle of sustainable development.
3. DEFINED: The Circular Economy Ethics and its value principle of sustainable development are systematically part of our processes.
4. INTEGRATED: We actively follow the Circular Economy Ethics and its value principle of sustainable development is systematically part of our processes. Our company has established new production ethics guidelines and protocols, to reflect the ethical attitudes to resources, environment, production and consumption.
5. EXPLOITED: Our organisation is a leading example of Circular Economy Ethics. Our processes fully rotate around the value principle of sustainable development and the related new production ethics guidelines and protocols, reflecting the ethical attitudes to resources, environment, production and consumption.

PARTNERSHIP

5.1 RESEARCH & INNOVATION

What kind of relationship does your company have with Research Institutes?

1. INITIAL: There are no relationships established.
2. MANAGED: Participation to events and workshops to create networking and foster the exchange of ideas.
3. DEFINED: We are active in joint Research & Innovation projects.
4. INTEGRATED: We collaborate in R&I projects involving data collection, data sharing and data analytics, to better understand C.E. patterns and impacts.
5. EXPLOITED: There is a systematic participation in common R&I programs, with technology transfer partnerships.

5.2 TRAINING & EDUCATION

What kind of relationship does your company have with Education and Training institutions, with specific reference to Circular Economy skills?

1. INITIAL: No C.E. competence assessment and training programs are planned.
2. MANAGED: Occasional competence assessment and training programs for a few C.E. roles.
3. DEFINED: C.E. competence assessment, training and education programs are done regularly.
4. INTEGRATED: Learning programs about C.E. are planned with educational institutions.
5. EXPLOITED: We have widespread lifelong learning programs and collaborations with educational institutions.

5.3 IT SOLUTION PROVIDERS

What kind of relationship does your company have with its IT providers?

1. INITIAL: There are no continuative relationship established.
2. MANAGED: IT providers support us with SW solutions for inventory, tracking and monitoring of products and raw materials.
3. DEFINED: With IT providers we have developed online platforms for sharing resources and data.
4. INTEGRATED: With IT Providers we have developed data exchange platforms, endowed with Data Analytics and AI capabilities.
5. EXPLOITED: Our engagement with IT providers is dynamic and seeks opportunities for mutual growth, ensuring that data plays a pivotal role in our commitment to sustainable practices and circular economic principles.

5.4 SUPPLIERS

What is the main level of involvement that your company establishes with its main suppliers, in a Circular Economy perspective?

1. INITIAL: Transactional relationships, following a traditional linear model.
2. MANAGED: Awareness relationship: suppliers are encouraged to comply with basic environmental regulations and adhere to minimum sustainability standards.
3. DEFINED: Collaboration relationship: we select suppliers according to circularity principles and engage them in circular design, product life extension, material efficiency, recycling, reuse.
4. INTEGRATED: Integration relationship: we have strategic partnerships where suppliers are viewed as key contributors to Circular Economy goals, such as: joint product development, closed-loop systems and collaborative efforts.
5. EXPLOITED: Full integration relationship: strategic partnerships with suppliers are systematic and encompass the entire product life cycle, with commitment to continuous improvement in circularity.

5.5 CUSTOMERS

What is the main level of involvement that your company establishes with its customer in the product development process?

1. INITIAL: No partnership with customers.
2. MANAGED: We collect basic feedbacks from customers, but we do not involve them in the product

development.
3. DEFINED: Collaborative approach: we actively seek and consider customers feedbacks on circular design, recyclability and other sustainability aspects.
4. INTEGRATED: We engage customers in co-creating products with Circular Economy principles in mind.
5. EXPLOITED: Customers are viewed as partners and we share with them continuous engagement and responsibility throughout the product life cycle; we promote consumers education and awareness.

5.6 INDUSTRIAL AGREEMENTS
Does your Company have relationships with other industry stakeholders for the adoption of common rules for the definition of voluntary B2B data sharing schemes, towards developing an industrial data space that fosters cooperation?
1. INITIAL: There are no relationships
2. MANAGED: Only informal communication and one-off share of information is established
3. DEFINED: There are supportive relationships and initial formal activities in place aimed at fostering data sharing schemes and supporting the development and functioning of data spaces.
4. INTEGRATED: The Company is engaged in bi- or multi-lateral contractual frameworks (Industry Agreement), but only a part of the building blocks required to develop an industrial data space are addressed.
5. EXPLOITED: There is a formal Industry Agreement in place, setting common rules and voluntary B2B data sharing schemes encompassing all stages of the data life cycle and covering all the building blocks required to develop an industrial data space (including for instance technical specifications, data specifications, governance and legal dimensions, minimum quality standards or common performance measures/ metrics).

PERFORMANCE

6.1 OPERATIONAL/ TECHNICAL
What approach does your company adopt for measuring operational performances (e.g. OEE)?
1. INITIAL: Operational performance is often not measured or understood
2. MANAGED: Descriptive Performance - Measurement and analysis of business KPIs are largely retrospective
3. DEFINED: Diagnostic Performance - Measurement of KPIs is clear. Attempt to understand the causes that affects events and behaviours
4. INTEGRATED: Predictive Performance - Measurement of KPIs is prospective. Statistical models and forecasts techniques to understand the future KPIs
5. EXPLOITED: Prescriptive Performance – future-oriented. Optimization and simulation to find the best course of action and operational KPIs measurement

6.2 ECONOMIC
What approach does your company adopt for measuring economic performances (e.g. ROI)?
1. INITIAL: Economic performance is often not measured or understood
2. MANAGED: Descriptive – Measurement of economic KPIs is largely retrospective
3. DEFINED: Diagnostic - Measurement of economic KPIs is clear. Attempt to understand the causes of events and behaviours
4. INTEGRATED: Predictive - Measurement of economic KPIs is prospective. Statistical models and forecasts techniques to understand the future KPIs
5. EXPLOITED: Prescriptive Performance – future-oriented. A decision making support system boosting optimization and simulation to find the best course of action and operational KPIs measurement

6.3 ENVIRONMENTAL
What approach does your company adopt for measuring environmental performances (e.g. water consumption per product)?
1. INITIAL: Environmental performance is often not measured or understood
2. MANAGED: Descriptive – Measurement of environmental KPIs is largely retrospective
3. DEFINED: Diagnostic - Measurement of environmental KPIs is clear. Attempt to understand the causes of events and behaviours
4. INTEGRATED: Predictive - Measurement of environmental KPIs is prospective. Statistical models and forecasts techniques to understand the future
5. EXPLOITED: Prescriptive – future-oriented. A decision making support system boosting optimization and simulation to find the best course of action and environmental KPIs measurement

6.4 SOCIAL
What approach does your company adopt for measuring social performances (e.g. welfare for employees)?
1. INITIAL: Social performance is often not measured or understood
2. MANAGED: Descriptive - Measurement of social KPIs is largely retrospective
3. DEFINED: Diagnostic - Measurement of social KPIs is clear. Attempt to understand the causes of events and behaviours
4. INTEGRATED: Predictive - Measurement of social KPIs is prospective. Statistical models and forecasts techniques to understand the future
5. EXPLOITED: Prescriptive – future-oriented. A decision making support system boosting optimization and

simulation to find the best course of action and social KPIs measurement

6.5 PRODUCT-SERVICE LIFECYCLE

Which dimensions of analysis are taken into account in the assessment of lifecycle of the products/services offered to the customers?

1. INITIAL: No product life cycle assessment
2. MANAGED: A few life-cycle aspects are included in some KPIs but occasionally
3. DEFINED: Life Cycle Costing (LCC) towards recycling, de- re-manufacturing KPIs
4. INTEGRATED: Life Cycle Costing + Environmental LCA towards Circular Economy
5. EXPLOITED: Life Cycle Costing + Environmental LCA + Social LCA towards Sustainability and Green Deal

6.6 SUPPLY CHAIN

Which dimensions of analysis are taken into account for the overall evaluation of your company's supply chain?

1. INITIAL: Performance is often not measured or understood
2. MANAGED: Only the most important physical performance of suppliers (e.g. punctuality, quality, operational flexibility)
3. DEFINED: Physical and Economical performance (purchase price, non-quality costs, delivery delays, lack of flexibility, etc.).
4. INTEGRATED: Physical, economical, sustainability performance for almost all the suppliers.
5. EXPLOITED: Physical, economical, sustainability and integration with other external sources (e.g., social media, weather)

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