RECLAIM Use Cases Definition & Operational Requirements #3

[July 2022]

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

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Abbreviations & Acronyms

Abbreviations & Acronyms	
ASN	Adaptive Sensorial Network
DOA	Document of Agreement
DSF	Decision Support Framework
DW	Dishwasher
FPGA	Field-Programmable Gate Array
ID	Identifier
IIoT	Industrial Internet of Things
IoT	Internet of Things
KoM	Kick-Off Meeting
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
MTBF	Mean Time Between Failures
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
PLC	Programmable Logic Controller
PMS	Performance Measurement Systems
RC	Robotic Cell
SCADA	Supervisory Control And Data Acquisition
TPmer	Gorenje's Internal Application
UML	Unified Modeling Language

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Summary

The RECLAIM project is focused on the development of smart physical and virtual solution for their demonstration into six heterogenous Pilots covering from good manufacture to industrial equipment to achieve a new digitalization approach on large industrial manufacturing lines near their obsolescence or the analogical to digital refurbishment in older but essential machines. The new demands of the Industrial Internet of Things, IIoT, are opening new opportunities that required new strategies for the real integration of digital solution into the traditional industries based in the refurbishment and re-manufacturing of large industrial equipment in factories, paving the way to a circular economy.

The main objective of the re-manufacturing approach from the RECLAIM concept is to guarantee the coexistence of new high digitalized machines with analogical ones at the same production line. The way to achieve such challenge is the implementation of a set of digitalization tools, physical and virtual, connected with the Internet of Things to obtain the necessary information for the advanced management of the complete production process. This goal is not just an economical matter, it is a mechanism for the productivity increase centered on the prevision and the efficiency increased. The refurbishment and the re-manufacture of active machines going into the digital obsolescence is a green deal goal link with the sustainability to reduce the waste produced in the cases where the machines are dismissed and to reduce product carbon footprint by the optimal maintenance and energetic performance. Furthermore, the digitalization is a tool for the market position of industries, and it could make the difference between competitors or market success.

In this sense, RECLAIM solutions integrated into one unique architecture a complete pool of technologies from the physical layer, smart and heterogeneous IoT sensor, new versatile and functional industrial PC or human interface machine, etc., with the advanced software based in machine learning and data analytic for the decision support tool and digital twins' virtues demonstration. Where the preparation and anticipation of the factories to be digitalized will guarantee the competitiveness of the European Industrial sector. RECLAIM solutions will allow the democratization of Digital tools, physical and virtual, independently of the industries size with a minimal inversion based on non-invasive approach where the focus is the technologies instead of the renovation of the machines and equipment. Although, the RECLAIM tools are focused from the technical point of view to support all industrial sectors, six used cases have been identified for the demonstration of the technological benefit of the RECLAIM tool set on the physical and/or virtual digitalization of ageing and long-term exploited machines. The sectors where RECLAIM solution will demonstrate the technological tool kits are going from goods manufacturer, footwear manufacturer, wood furniture manufacturer, friction welding machines and original equipment manufacturer to home textile manufacturer with the aim to transform them into the IIoT age. These technological demonstration activities will address the future transference of the RECLAIM technologies to the complete industrial spectrum of Europe because of the modular approximation that guarantee the scale-up of the RECLAIM solutions.

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RECLAIM Use Cases Definition & Operational Requirements #3

The D2.7 deliverable, deliverable, RECLAIM Use Cases Definition & Operational Requirements #3, in its third deliverable of T2.2. The deliverables of T2.2 are proposed as a subsequent evaluation of the Use Cases Definition & Operational Requirements along the project evolution on the technical and demonstration activities. With special emphasis on the Key Performance Indicators evolution of the RECLAIM project and their impact in the demonstration activities. The task T2.2 together with T2.1, focus on End-User requirements including external survey, T2.3, the vision of the RECLAIM project technological approach, collect into a structured view the requirements, the definition of the industrial Use Case, the technical solution Architecture and the metric for the technical development and the demonstration result measurement, the Key Performance Indicator. The Key Performance Indicators, KPIs, proposed at Grant Agreement has been and their confluence into the most important ones to guarantee the Pilot demonstration activities evaluation has been performed at the present deliverable D2.6.

The RECLAIM industrial Use Case where structured into six Pilots, the white goods demonstration lead by Gorenje (Pilot#1 and #2), the footwear manufacturing pilot lead by Fluchos (Pilot#3), the wood furniture fabrication lead by Podium (Pilot #4), the friction welding machines demonstration lead by Harms & Wende (Pilot#5) and the bleaching machine pilot for home textile manufacture lead by Zorlutek.

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Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 869884

List of Figures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°869884

List of Tables

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 869884

1 Introduction

The D2.7, RECLAIM Use Cases Definition & Operational Requirements #3, deliverable of RECLAIM project is focus on the evolution of the Key Performance Indicators of the project for the measurement of the impact of RECLAIM solutions into the demonstration activities of the project, as well as other general project activities. Two previous deliverables have been reported, D2.2, #1, as the first version of the RECLAIM Use Cases definition and the compilation of the overall project KPIs. At this deliverable, a detailed description of the six industrial Use Case for the refurbishment and re-manufacture based in digital and smart sensors solutions were reported. The second version of the deliverable, D2.6, #2, as the where subsequent version of D2.2, #1, were focused on the deep analysis of the prioritized KPIs and its alignment into the RECLAIM Use Cases. At this deliverable Unified Modeling Language diagrammed, UML, describing the interconnectivity of the six industrial Use Cases defined for the RECLAIM solutions demonstration were reported. The D2.6 were completed with the Use Case description.

At the present deliverable the focus has been done at the selection of the most impacting KPIs on the RECLAIM demonstration activities as well as the most impacting ones for the industrial sector as the basis for the impact measurement of the technical solution of the RECLAIM project and their demonstration activities at the WP6.

The methodology followed during the T2.2 activities for the definition of the requirements, the technological solution identification for the demonstration and the architecture definition was extensively presented at D2.2, nevertheless the following figure shown the task methodological approach. The detailed description and definition of the Use Cases based on this methodological approach was the fundamental basis for the early Pilot activities definition.

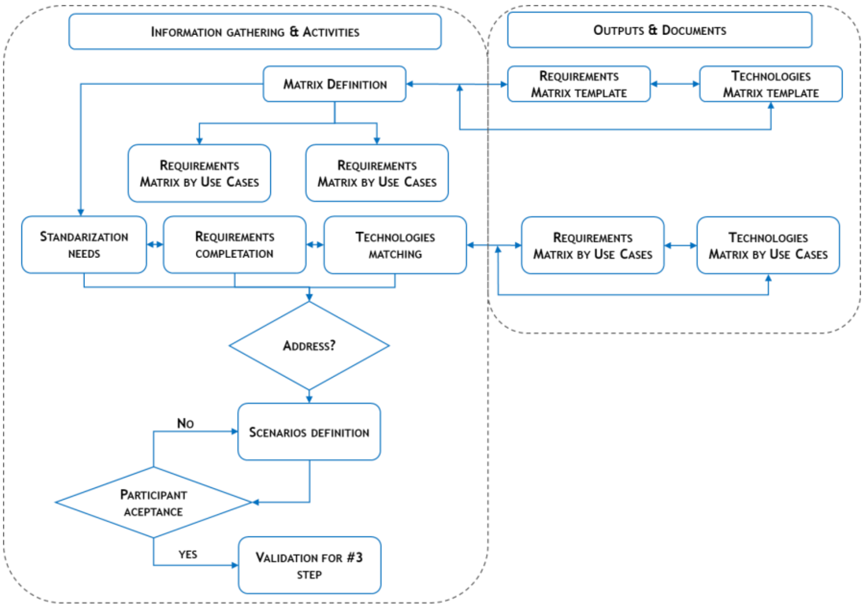

Figure 1.- Task 2.2 methodology diagram

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Besides that, and with the aim to obtain a structured view of the relationship between the different RECLAIM technological solutions to be demonstrated at the pilot during WP6 activities, the UML diagrams for all the pilot specific solutions were carried out and presented at the D2.6, RECLAIM Use Cases Definition & Operational Requirements #2, the second version of the deliverable.

The third main core activity of the T2.2 is focus on the KPIs understanding and analysis for the pilot impact and RECLAIM solution impact measurement. The 35 KPIs proposed at the grand agreement were analysis by RECLAIM industrial consortium member leader of the pilots and the technical providers for the RECLAIM solutions to identify those KPIs applicable to each pilot and industrial sector.

The transformation of the high-level description of the industrial use-cases into realistic requirements and reachable demonstration scenarios is a long-term activity that evolve along the project execution based in the constant approach between technical capabilities and end-user requirements. To visualizes the technical potential of the RECLAIM tools on the digitalization into practical Use Cases six practical Pilots has been define. The activities have been structured into three main steps. The first one reported in D2.2 was focused to the requirements establishment and their understanding into practical specifications, general or specific depending on the technology and the pilot industrial actor and sectorial needs. The second one, based on the previously mentioned is to materialize this specification into practical operational diagram where the specific technical solutions will be used and implemented during pilot's demonstration. And the third one, is the KPI metric definition and valorisation into RECLAIM project results. At this deliverable, and KPIs proposition are described and compiled.

The document is structured in four sections to conduct the reader onto the advances on KPIs prioritisation based on the RECLAIM objectives as result of the analysis done by the consortium members during the May 2022 General Meeting, the analysis of this KPIs into each Use Cases, the position of this main KPIs into a general industrial KPIs architecture and the Use Cases presentation.

The first chapter is this introduction to the document contents. The second chapter is focused on the overall project KPIs prioritisation carried out by the consortium during the face-to-face general meeting of May 2022. The analysis of the prioritised KPIs on the objective's framework is also included at this section. The third section is focus on the understanding of each pilot for this prioritised KPIs. Followed from the categorization of the main KPIs into the general key indicators mainly used of at the industrial sector. To finalised with a short summary of the industrial Use Cased defined at RECLAIM project for the demonstration of the developed technical solutions for the refurbishment and re-manufacturing of machinery and production lines at the industrial sector.

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2 KPIs prioritisation according to the RECLAIM objectives.

A compendium of Key Performance Indicator, KPIs, of the RECLAIM project, were proposed at the Grant Agreement, see Annex A. The 35 KPIs proposed at this document were aligned with the project objectives following the WPs structure of the project.

During the project development, several exercises were carried out to understand the impact of these KPIs into the different Use Cases and how they impact into de Pilot for the demonstration activities. The analysis was conducted at WP2 and WP6 activities into the following steps:

- **Selection of the relevant KPIs involved in each Use Cases**. Due to the different nature of each industrial sector represented at RECLAIM project by the industrial actors Gorenje (home appliance manufacturer) lead of the Use Case #1 and #2, Fluchos (shoemaking industry) lead of Use Case #3, Podium (high-end wooden furniture manufacturer) lead of Use Case #4, Harms & Wende (friction welding machine manufacturer) lead of Use Case #5 and Zorluteks (producer of cotton home textiles) lead of Use Case #6 was analysed the impact of the overall KPIs into each pilots.
- **Approaching the general RECLAIM KPIs into the 6 Use Cases**. A more detailed description of the KPIs or their nuance was presented at D2.6 for each Use Case for a better definition of the KPI influence on the specific pilot, machinery or sector.
- **Categorization of the RELCAIM KPIs into the general industrial KPIs classification**. Key Performance indicators is an impact measurement metrics intensively used for the evaluation of the objective's consecution. This metrics allow the industries to define measurables unit at machinery, process, factory or the overall industry to monitor the results and to propose actions for the decision making. The categorization of the RECLAIM KPIs, focus on the impact of the refurbishment and re-manufacturing based on digital and smart technical solutions, into the general industrial KPIs allowed to the conclusion that the most impacting indicators are those linked with the productivity and planification.
- **Prioritisation of RECLAIM KPIs according to the project objectives**. The management of 35 KPIs and its variants (KPIs defined or adapted for specific Pilots) to measure the Pilots results and the RECLAIM technical solutions could be a very difficult task and could mask the real impact. The process of selecting KPIs is difficult because of the wide range of alternatives. And with the aim of the correct identification of adequate KPIs to obtain a greatest benefit a prioritisation according to the project objectives has been performed. This prioritisation has been focus on the selection of an adequate

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number to achieve measurable results, where the real impact of the RECLAIM KPIs is applied.

1. Selection of the relevant KIPs involved in each Use Cases
2. Approaching the general RECLAIM KIPs into the 6 Use Cases
3. Categorization of the RELCAIM KIPs into the general industrial KIPs classification
4. KIPs prioritisation according to the RECLAIM objectives

Figure 2.- Steps of RECLAIM KPIs analysis.

The prioritisation exercise has been conducted during the RECLAIM face to face General Meeting (M30) of May 2022, at San Sebastian and Arnedo (Spain) in the Tecnalia, CTCR and Fluchos facilities, see figure. The General Meeting opened the opportunity to the consortium, conducted by Oscar from Information Catalyst For Enterprise Ltd, of the working groups organization for the KPIs analysis and discussion.

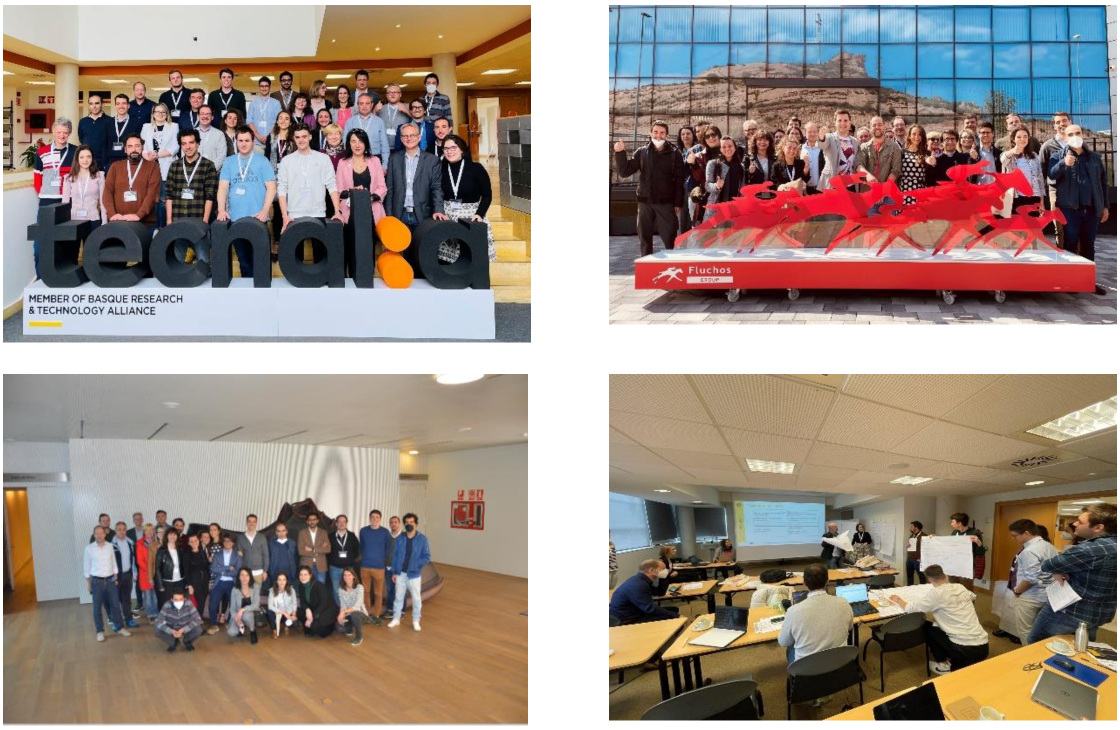

Figure 3.- M30 General Meeting at San Sebastian and Arnedo, Spain, organized by Tecnalia, CTCR and Fluchos.

The aim of the prioritisation exercise was the selection of the most relevant and impacting KPIs for the Pilot demonstration activities measure at WP6. The metrics units, KPIs, should be aligned with the project objective, due to the fact that project objectives are the goal to achieve during the project execution. Once, the strategy was defined: to select the measurable units, KPIs, aligned with the RECLAIM

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objectives for the Pilots demonstrations activities monitoring to establish the RECLAIM technical solution impact in the refurbishment and the re-manufacturing of industrial machinery to avoid their digital obsolescence; the RECLAIM team have been working on the prioritization. The result was the reduction of the initial 35 KPIs to 7 KPIs shown at the following figure.

Figure 4.- Task 2.2 methodology diagram

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The K2.1 linked with the objective O2 is focus of the reduction of the inspection cost at the factory plan because of the use of smart sensor network. The smart sensor able to supervise a huge number of machineries and manufacturing lines could increase their impact into the cost reduction when the supervision is carried out at real-time, if possible, or near real-time, small delays due to the systems and process complexity. This KPIs allow the RECLAIM solutions to achieve the O2, where the development of tools for the support on the decision making is the goal. Mainly, focus on the inspection and the planning of the refurbishment and re-manufacturing actions.

Figure 5.- K2.1 KPI link to O2.

The O3 is link with the K3.2, where the effort shall be focus on most complex toolkit for the production and machinery monitoring complementing the smart sensorial network on the refurbishment ad re-manufacturing of industrial electromechanical machinery. The combinate use of smart sensor networks and clod computing advance solutions could increase the impact of the RECLAIM technical solution application into industrial pilots.

Figure 6.- K3.2 KPI link to O3.

Focus on the planification, unscheduled actions on maintenance reductions, K4.4 and K4.5, are high costly takes that the industries would like to solve and the development of technical solution like those developed at RECLAIM project could increase the prediction and early diagnosis of machine failures.

Figure 7.- K4.4 and K4.5 KPI link to O4.

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One of the most impacting factors on productivity is the time, and the reduction of the time on failures reparation or the planification of corrective actions to avoid failures are translated into cost reduction. This is the main impact of K6.1 into the industrial sector. And the large-scale implementation of RECLAIM solution could help on the refurbishments of the European industries and the approaching of obsolete machines into the Digital Age.

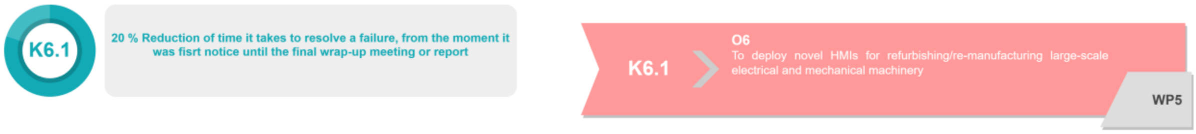

Figure 8.- K6.1 KPI link to O5.

The K8.2 is mainly most focus of the RECLAIM project result, and it is a measurement unit of these results. The project technical solutions will be implemented partially into 8 different machines of the 6 Use Case that are being demonstrated at the different pilots at WP6. The main aim of this activity is the validation of the RECLAIM technical solutions for the refurbishments and re-manufacturing of industrial machines and process. The overall RECLAIM solution could not be implemented as a hole into all the Use Cases, due the particular need of each Pilots. Specific demonstration of different part of the RECLAIM solution has been proposed for their validation at WP6. The K8.3 KPIs is most difficult to be measured due to the long-time need for the KPI measurement, that, also, exceed the project timeline.

Figure 9.- K8.2 and K8.3 KPI link to O8.

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3 Use Cases Definition summary

This chapter focuses on the evolution of the scenarios starting from the results that were obtained on D2.2 'RECLAIM Use Cases Definition & Operational Requirements #1' on the chapters 5 and 7. On these chapters, the pilot scope and the use case scenario were shown, defined by Gorenje (Pilot#1A and #1B), Fluchos (Pilot#2), Podium (Pilot#3), Harms & Wende (Pilot#4), Zorluteks (Pilot#5) and the collaboration from the technological provider partners constituted by ADV, CERTH, CTCR, FCY, FEUP, FINT, ICE, ROBOTEH, SCM, SUPSI, TEC and TTS.

The main elements for each pilot are summarised below:

- **Pilot#1A.** Refurbishment and renovate Robot cells for making dishwasher tubs. Some important equipment adjustments have been made to keep up with the development of new types of dishwashers.
- **Pilot#1B.** Modernization and refurbishment of White Enamelling line. It is interesting to re-use very old industrial equipment for stable improved production processes with less machine failure, increase the effectiveness and optimize production processes, reduce maintenance and production costs, reduce environmental impact.
- **Pilot#2.** Shoemaking industry has a complicated production process that requires more than 200 operations, a great deal of industrial machinery, such as cutting machines, industrial sewing machines, skiving machines, moulding machines, grinding machines etc., and is a labour intensive procedure, requiring manual intervention in many operations, such as shoe lasting.
- **Pilot#3.** Podium manufacturing line deals with the production of high-end wooden kitchens. The line covers 1800 m^2. It processes 500 pieces per day. The system is composed by machines from several vendors interconnected. These machines work over one shift of 8.4 hours.
- **Pilot#4.** The pilot case is built around a friction welding machine. Such machines are used for the reliable joining of welded metal parts and for a huge variety of materials like steel, aluminium, ceramics, brass, copper etc. Friction welding can also be used with nearly no conductance of the materials and independently from surface quality e.g. zinc, lacquer, or enamel.
- **Pilot#5.** Zorluteks Textile Company has a large variety of products including home textiles (curtains, roller blinds, bed sheets, bed linens, bed covers, table clothes, coverlets, etc.). In this Pilot use case, the Bleaching Machine will be tested, which is used for bleaching the raw cotton fabrics. The function of bleaching is to remove blue-absorbing yellow contaminants.

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Figure 10.- Pilot's overview diagram.

A further definition of the use cases has been carried out in this iteration, for a major understanding of the technical aspects of the use cases, a definition of solution for pilot demonstration and the interrelation among the different components (hardware, software, algorithms, etc) and the system flows. As it could be seen in the following subsections.

3.1 Pilot #1 - Home Appliance Manufacture

3.1.1 Pilot #1A

Robotic Cells, RC, are one relevant production line tool at the manufacturing process in Gorenje dishwasher, DW, factory. Dishwasher inox tubs, which are the main part of dishwasher are manufactured and isolated in robotic cells, where bending, punching, edge profiling, pressing, welding, isolation processes are carried out mainly by automatized robots. Most of the semi-finished products come from the pre-manufacturing of the raw material section (sheet metal presses); the basis of the DW tub are the L sheet (bottom / back) and the U sheet (sides and top). Insulation parts are a product of external suppliers. RCs for the manufacture and isolation of DW tubs are a set of cells called XL, A, B, C, D and E. The process is supervised by operator.

At the beginning of cell A, the order is displayed as a PLC code, and according to this code, a label is printed and fixed by the worker to the U panel.

This code is used for statistics, mainly for counting semi-finished products. The PLC code serves as information in certain crucial places (e.g. making holes, etc.). The system is deficient, insufficient, and unreliable. Full automotive and effective manufacturing is necessary to avoid many problems.

In cell A the following will be implemented:

- vision camera and image processing software for object recognition (anomaly recognition),

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- sensors for 2 storage containers to detect if storage is on minimum level,
- predictive of welding electrode and punching knifes worn out; PLC data will be used,
- predictive of hydraulic oil change; different sensors (temperature, oil level…) will be installed. PLC data will be used,
- monitoring of robot and other equipment operations for predictive maintenance and compute KPIs.

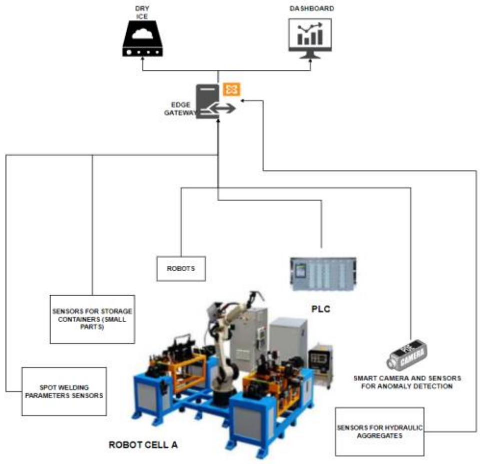

Figure 11.- Gorenje 1A Field-Related diagram Cell A.

In cell B and C, the following will be implemented:

- predictive of welding reels worn out, predict changing of reels. PLC data will be used.
- vision camera for online welding quality control,
- monitoring of robot operation and other equipment for predictive maintenance and compute KPIs; PLC data will be used,
- predictive of hydraulic oil change; different sensors (temperature, oil level …) will be installed. PLC data will be used,
- water flowmeter for water consumption monitoring.

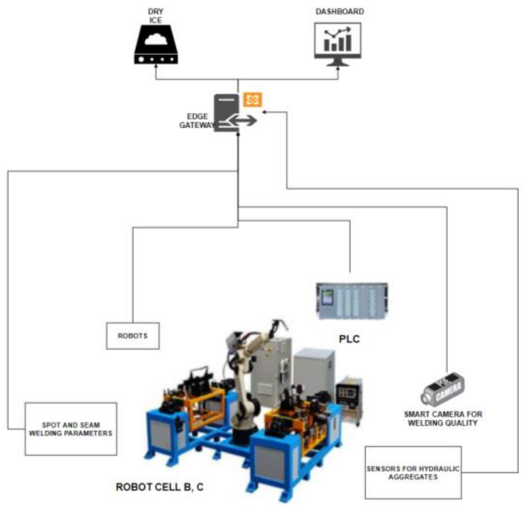

Figure 12.- Gorenje 1A Field-Related diagram Cell B and C.

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In cell D, OBC will be implemented:

- monitoring of robot's operation and other equipment for predictive maintenance and compute KPIs; PLC data will be used,
- predictive of welding electrode worn out, PLC data will be used.

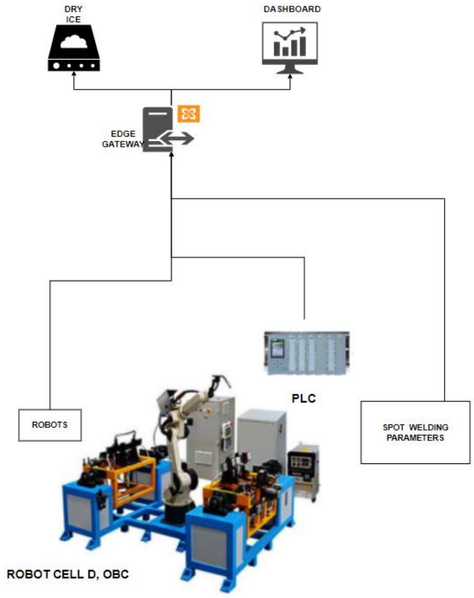

Figure 13.- Gorenje 1A Field-Related diagram Cell D and OBC.

3.1.2 Pilot #1B

White enamelling line is the most important production line for cooktops in cookers manufacturing at Gorenje/MORA company. The enamelling process consists of several stages:

- degreasing line (dirty raw cooktops coming from presses are decreased from oils).
- automatic spray booth for enamel powder application with recycling filter unit.
- infra-red dryer.
- manual re-hanging from one powder conveyor to furnace conveyor.
- gas furnace.

Current technology is based in one side spraying of powder enamel, one piece (cooktop) is hung on the hook, with the upgrading of actual line to two pieces (cooktops) per hook, big increase of efficiency of the enamelling line is expected.

There will be implemented two cameras for recognition of different variants of cooktops at the enter of the white enamelling line. On the 8 places near the line will be placed wireless sensors for measuring temperature and humidity. One position will be outside of hall to register outside conditions. At the end of the line enamelled cooktops are checked and wrong parts sorted and registered on touch screen according to type of fail and type of cooktop.

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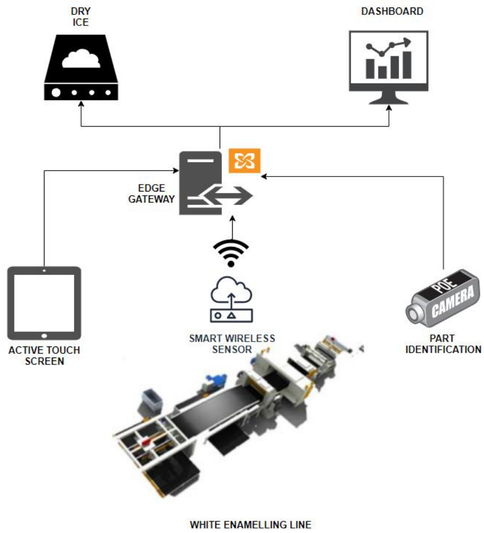

Figure 14.- Mora Field-Related diagram.

3.2 Pilot #2 – Shoemaking Industry

The scope of this pilot is to improve the productivity of this machinery, since most of the equipment is over 10 years old and it does not have a modern monitoring or electronic control to manage the manufacturing operation and the operating parameters in an accurately manner. Two machines are being digitized, the rear part forming machine and the front part forming machine.

The rear part forming machine, Talonadora, is used for joining a pad in the lower part of the shoe, for making the heel more comfortable. This process consists of two similar steps. In both ones, the operator puts the shoe in the last, then, by pressing two buttons, the fixative mould goes down until it touches the shoe, which is between the mould and the last.

The front par forming machine, Rotostir, consists of a rotative base where the operator puts the shoes. Then, with a roller, the front of the shoe is given its final form, fixing it with the down part. Left and right shoes are alternate, so the operator must put each one in the correct mould. Then, by pressing two buttons, the machine tours. The left part of the machine fixes the left shoes, and the right part does the same with the other pair.

Talonadora

To have a better knowledge about the boundary conditions of this process, there has been installed on the machine different sensors and equipment within the activities performed on the WP3.

The cold bulb temperature must be around -9,9 ºC. If the temperature is over that value, the fixation between the shoe and the pad could be wrong, resulting in a defective product. If the temperature is lower, the last could get frozen, leaving it useless for a long time.

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The hot bulb temperature must be around 122 ºC. If the temperature is over that value, the shoe could get burned, having a bad aspect and, for last, be wasted. If the temperature is lower, the fixation will not be correct.

Controlling these parameters will lead to any of the deviations that could appear would be registered with the objective of predicting possible failures.

In addition, the deformation on the bulb will be monitored by a flexible sensor.

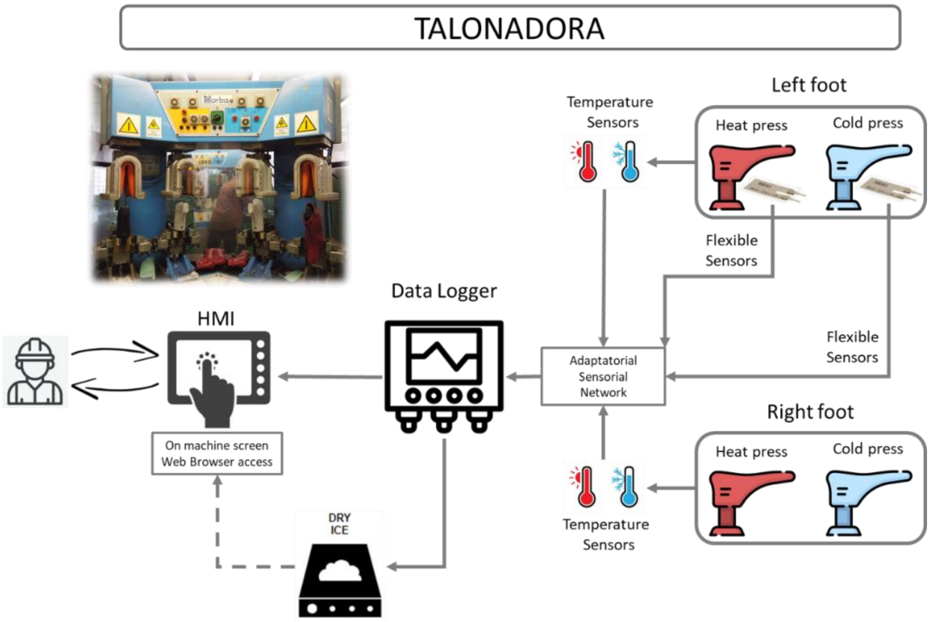

Figure 15.- Fluchos Talonadora Field-Related diagram.

The information gathered with the sensors to control the temperature and the deformation of the bulb, will be send by MQTT to the DryICE platform and will be analysed and check for possible deviations.

Rotostir

To have a better knowledge about the boundary conditions of this process about the PLC states and the power consumption of the machine, there has been installed on the machine different sensors and equipment within the activities performed on the WP3.

The equipment that have been installed in this machine, is for reading parameters about power consumption. In each power line from Rotostir there are:

1) V Lx: voltage of each line, that must be divided by 10 to have the magnitude in Volts.

2) I Lx: intensity of each line, that must be divided by 1000 to have the magnitude in Amperes.

3) P Act Lx: active power of each line, that must be divided by 1000 to have the magnitude in kilowatts.

4) P React Lx: reactive power of each line, that must be divided by 1000 to have the magnitude in volt-ampere reactive.

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These parameters should be very similar in the three lines, which would reveal that the installation is well balanced. If not, it must be fixed, because any imbalance can change into an overload, causing the machine breakdown.

In addition, the control parameters from the machine PLC will be extracted and merge with consumption parameters and all the parameters that brings the rotation motor, in order to know better the different stages of the process and analyse the implications of each stage of the process with the consumption.

All the data gathered from the Rotostir will be merge in a JSON message and send by MQTT in order to have in DryICE platform to be analysed.

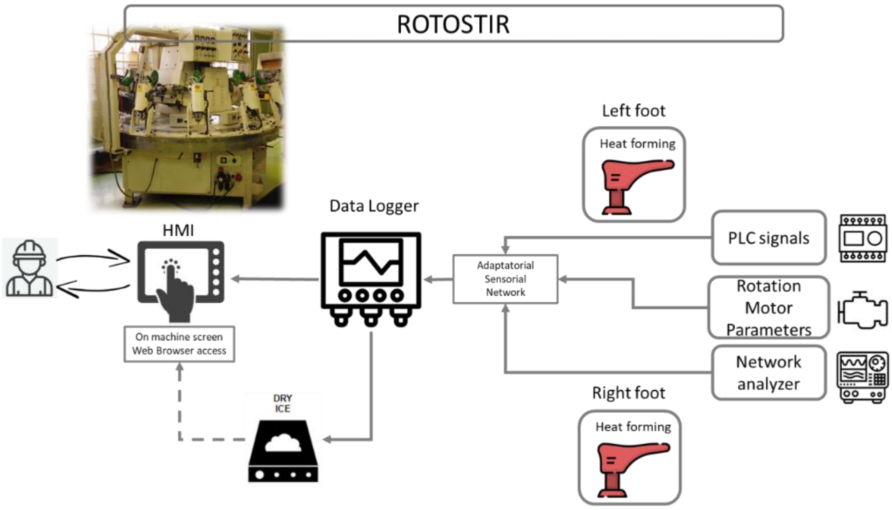

Figure 16.- Fluchos Rotostir Field-Related diagram.

3.3 Pilot #3 - Woodworking Production

Furniture manufacturing (i.e. to produce box-shaped cabinets) can be broadly summarized into 6 main steps carried out by different specialized machinery types.

1. **Storage:** Wood-based panels in standard sizes are moved into the factory and to the main working stations.
2. **Cutting:** Wood-based panels are cut into desired shapes and sizes.
3. **Edge Banding:** The exposed sizes of the panels are covered by customized materials strips.
4. **Drilling:** Holes are drilled in different panel points in order to prepare for assembly and insert metallic components.
5. **Finishing:** The panels are given different surface textures according to the requested aesthetic features.
6. **Assembly and packaging:** The cabinets are assembled or packaged in order to be assembled by the buyer.

With the digital retrofitting of the drilling machine and the digitalization of the edging machine, Podium can make a reliability analysis of these production processes.

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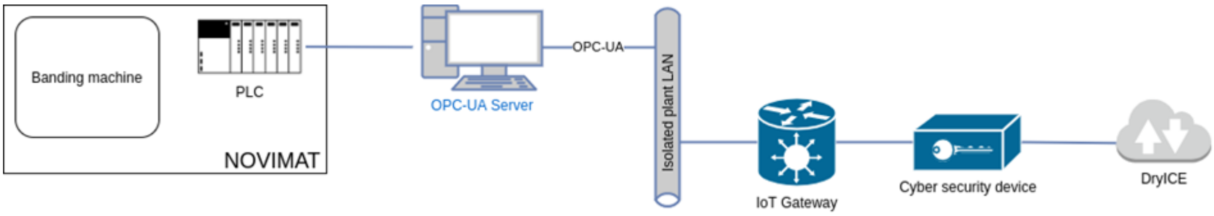

Figure 17.- Podium Field-Related diagram

The results of the analysis could be integrated in the digital twin shop floor simulation that allows Podium to analyse different scenarios about for example changes on production or maintenance plan, and so on. Digital Twin can also understand the machines behaviours through simulated different scenarios, in fact it is directly connected to the predictive maintenance approach and anomaly detection, in order to optimize the time management of the production. Other important information that Digital Twin receives are the LCA tool data that allows the simulator to consider the production behaviour from other side.

The entire solution allows Podium to optimise the production scheduling and to facilitate the make decision process.

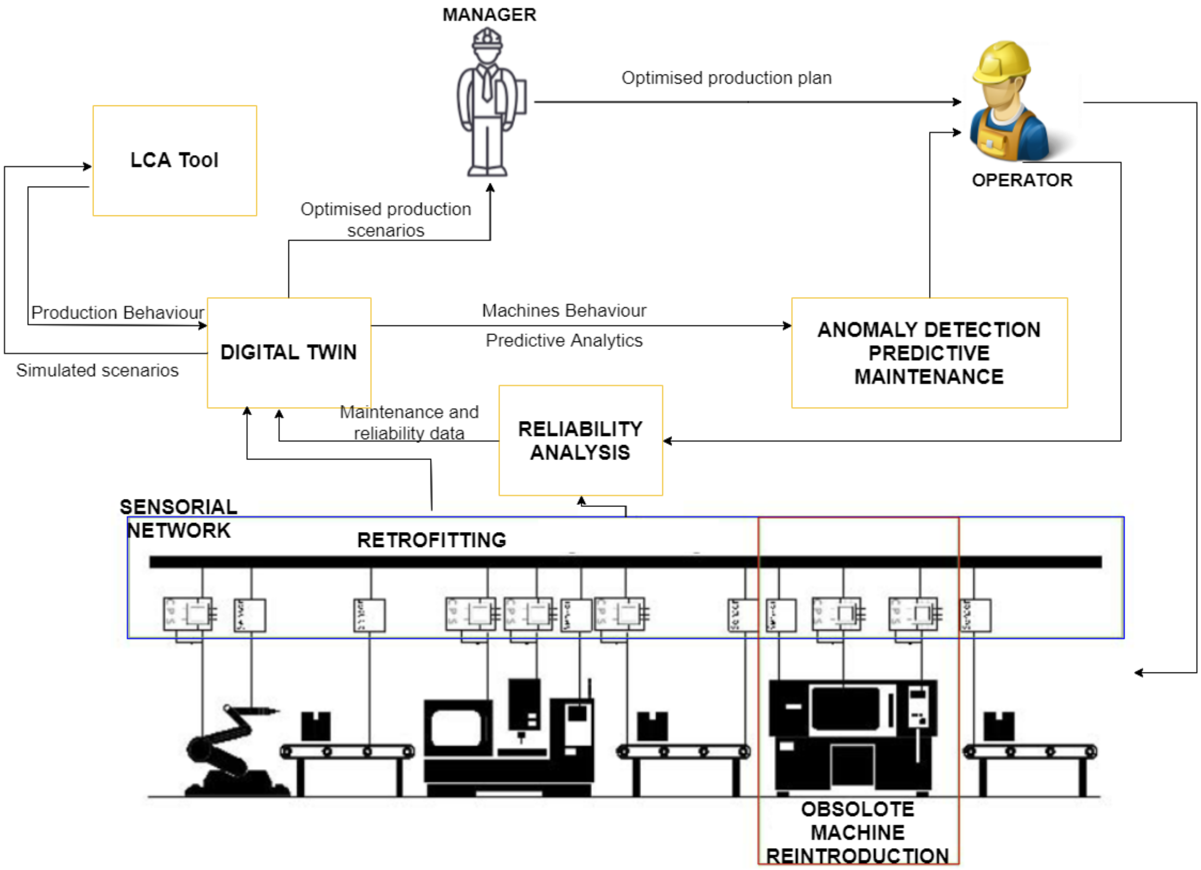

Figure 18.- Podium integration of the set of solutions diagram.

The picture above represents the integration of the set of solutions envisaged in the project. In addition to the three solutions already explained, there are also:

Anomaly detection methodology & Information modelling tool

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The pilot-agnostic methodology for anomaly detection and predictive maintenance will be applied to the drilling machine MAW ABS 110 and to the edging machine IMA NOVIMAT.

By exploiting both historic and digital twin acquired data, the information modelling tool will be exploited to provide updated information related to the state of the machines in terms of reliability and lifetime expectancy. The tool will be firstly adopted to monitor and evaluate the situation of the edging machine, analysing the specific equipment composing them, wherever possible.

The tool will be therefore taken as a starting point to structure a more thorough analysis of production system reliability related issues and keep a continuous monitoring of system across time.

3.4 Pilot #4 – Friction Welding Technologies

Harms & Wende intends to update and to significantly enhance their traditional welding devices by predictive maintenance features. The pilot scope is the re-manufacturing and upgrading of friction welding machine RSM401, including the use of *advanced sensors* and on *data analysis* of the gathered data.

Within the re-manufacturing and upgrading processes the focus is on the following aspects:

- sustainable system design to produce future-proof welding systems.
- use of identical parts to reduce production costs and improve service as well as maintenance of the welding systems.
- proactive and tailored service through predictive maintenance.
- ensuring holistic resource efficiency.
- fast, user-friendly, energy-efficient system design.
- smart management and operation.

HWH friction welding machines are currently controlled by a standard PLC. According to the internal strategy of increasing the depth of the added value, the PLC shall be replaced by the HWH product Genius. This conversion is a basic requirement for the implementation of RECLAIM technology. The connection between the Genius to the HWH software XPegasus provides data storage and data analysis functionality. Furthermore, XPegasus is also connected to the RECLAIM sensor gateway, which communicates process data to the RECLAIM data repository DryICE. A use case defined by Harms&Wende is to develop an interchangeable Human Machine Interface (HMI) with which friction welding systems can be operated both via a connected control panel and via mobile devices. One of the important requirements is remote monitoring of the equipment either from withing local Network or/and Internet. Monitoring implies observation of sensor and process data, equipment status, degradation state, etc. To meet the requirements, we implemented widely used standard interfaces for data communication and exchange. After defining the gap between current sensors and data needed for further monitoring applications e.g. quality, process as well as machine monitoring for predictive maintenance the types of sensors were selected, and their installation location were discussed. The

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introduction of a standardized modular system will make it possible to replace components with equivalent ones or to upgrade or downgrade them.

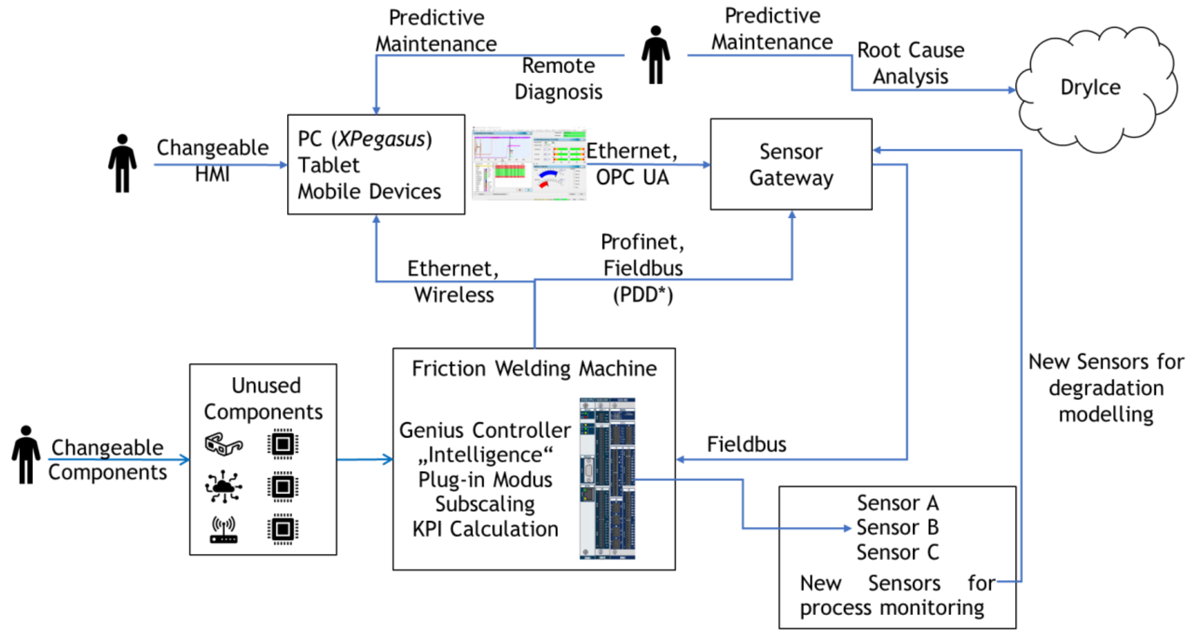

Figure 19.- HWH Field-Related diagram.

3.5 Pilot #5 - Textile Manufacturing

Raw cotton, like all-natural fibres, has some natural colouring matter, which confers a yellowish-brown colour to the fibre. The purpose of bleaching is to remove this colouring material and to confer a white appearance to the fibre.

The objectives of bleaching are described below:

- The main objectives of bleaching are to get a sufficiently high and uniform degree of whiteness in the textile materials.
- To get a high and uniform absorptivity in the textile materials.
- Bleaching agent occur some damage to the textile materials. So, bleaching must be accompanied with minimum fibre damage.
- To preserve a good user and technological properties of the textile materials.
- The process must be ecologically and financially sensible.
- To accelerate the next dyeing process.

The bleaching process is carried out in order to obtain a constant whiteness value in cotton fabrics. Bleaching, which is one of the most important steps in textile pretreatment processes, is carried out in bleaching machines. The most important purpose of the bleaching process is to obtain white fabrics by removing the ecru color originating from the natural structure of cotton.

Zorluteks has three continuous bleaching machines. The difference between the three bleaching machines is their working width. The maximum working speed of the machines is 100 m/min.

In Bleaching Machine there are a total of 7 washing chambers, 2 before the steaming chamber and 5 after. Wetting is given to the fabric in order to increase its hydrophilicity at the entrance of the washing baths. Afterwards, the fabric goes through two washing baths with water at 95˚C and 85˚C, and it is purified from the desizing chemicals left over from the previous process.

Then, bleaching chemicals are given to the fabric in the foulard (flexnip) located at the top of the machine and the fabric passes into the steaming cabinet right next to the Flexnip. In the steaming cabinet, the fabric is kept at a temperature of around 102˚C for 18 minutes, and bleaching reactions occur. Then the fabric passes through the washing baths located at the bottom of the machine. In the washing baths section, rinsing is carried out in baths 3-6 at 95˚C and neutralization is carried out in the last bath. In the first part of the last washing bath, which is double chambered, there is water containing acetic acid for fabric neutralization. The tank pH is adjusted between 4-5. In the second part, after the fabric is rinsed and the excess water is removed, it passes through the sensors (named mahlo) to prevent the fabric from entering unevenly in the weft direction. Finally, the fabric passing through the dryer is wrapped on the batching trolley at the exit.

The equipment that will be installed in this machine, is for reading necessary parameters about the bleaching level and its correlation with the different states of the machine:

- *Whiteness Degree of the Fabric*. - The parameters that are the most effective on the whiteness of the fabric were investigated and found by laboratory tests. Then, a search was made for an online whiteness sensor, it was decided that the most suitable technology was in the Shade Bar whiteness measuring sensor, and a demo sensor was installed on the bleaching machine.
- *Multiparameter Chemical Sensor*. - Measure the main chemical parameters of the process. In only one device will be merged different sensor to gather all the important information from the recipe.
- *Industrial Camera*. - For the whiteness prediction with deep learning process in scope of T5.2, Zorluteks purchased an industrial camera which specifics were determined with CERTH. Its installation was made at the end of September. This camera can be seen in the Figure 12. The camera system ensures that a certain area of the fabric is photographed periodically and stored in the desired folder by naming it.
- *PLC/SCADA*. - Extraction of the data that is being monitored by the SCADA system and it is needed to be merged with the rest of information from the different sensors.

The data gathered from the shade bar cameras and the industrial camera will go through a PC installed at Zorluteks, analysed on that PC and the results will be send to the DryICE platform.

The data gathered from the chemical sensor and from the PLC will be merge in a JSON message and send by MQTT in order to have in the DryICE platform to be analysed.

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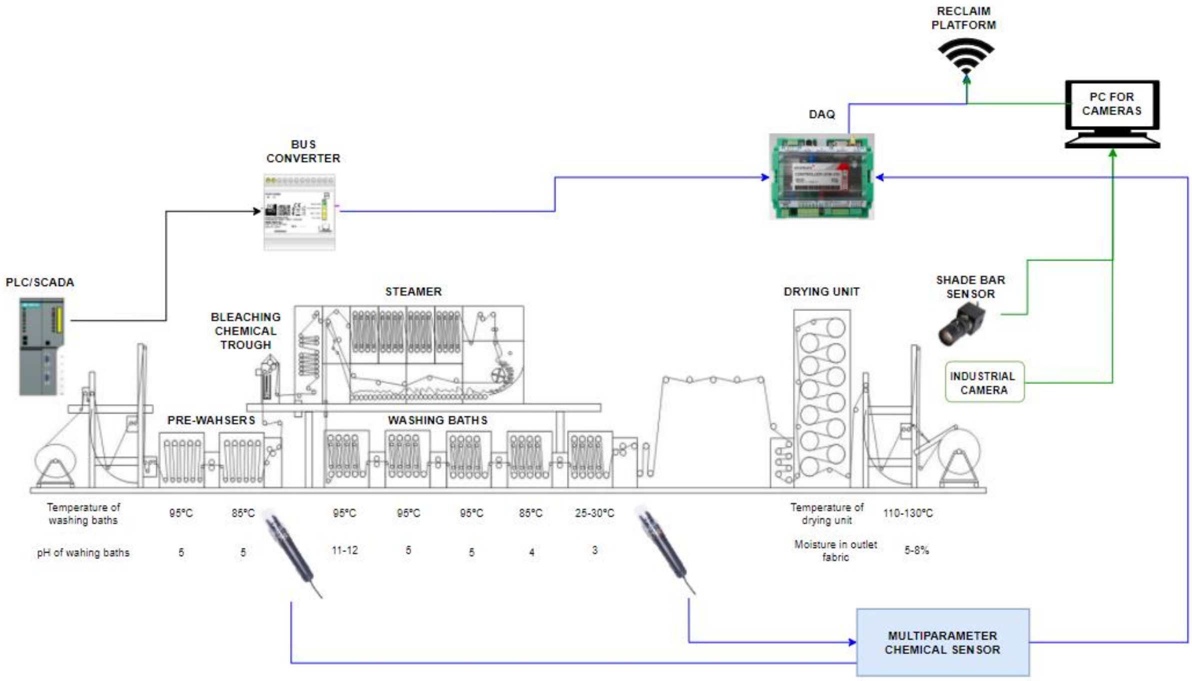

Figure 20.- Zorluteks Field-Related diagram.

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4 Use Cases approach to the principal KPIS

As mentioned previously, it is worth noticing that KPIs must be adjusted to fit each Use Cases scenario. Indeed, since the use cases belong to different industrial sectors, with different machines and production processes, the calculation metrics beyond each KPI must reflect the different requirements in each pilot, as well as it has been done with the RECLAIM technical solutions.

At this section, it is summarized the understanding of each measurement unit done by the RECLAIM actors involved in the pilot.

4.1 Pilot #1 Home Appliance Manufacture

4.1.1 Pilot #1A - Refurbishment and renovate 2 Robot cells in B-Cell for making tubs DW40 Home Appliance Manufacture.

The Pilot #1A is focus on the home appliance manufacture sector and specifically on the refurbishment and the renovation of the robotic cells of the manufacturing plant. Their main specific KPIs are detailed below, together with their declination in the specific pilot case.

Table 1.- Approach of Pilot#1A to K2.1

K2.1	**50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring**
Currently, there are not so much physical inspections on the line. Nevertheless, the new components and the new sensors, that will be implemented on the robotic cells, will support to achieve this reduction and to have good figures at the present KPI. As initial approach, Gorenje believes that it could be in the range of 50% of cost reduction.	

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Table 2.- Approach of Pilot#1A to K3.1.

K3.2	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
Gorenje is considering using this Toolkit for this pilot. Nevertheless, it will be evaluated more in detail during the next months based on the applicability to this pilot of the technical solutions and algorithms.	

Table 3.- Approach of Pilot#1A to K4.4 and K4.5.

K4.4	**Reduction of at least 20% of downtime due to unscheduled maintenance**
The downtime is monitored at Gorenje by their TPmer system and it will be available for KPI calculation.	
K4.5	**Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)**
The Mean Time Between Failure, MTBF, is actually over 8-10 days. It will be difficult to estimate the MTBF even if there are the support of the prediction tools for maintenance activities planification. Gorenje consider that 50 % is high value to be achieved.	

Table 4.- Approach of Pilot#1A to K6.1.

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K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
This value currently is not measured by Gorenje due to this kind of problems they solve as soon as possible but without urgent because the production process could continue running.	

Table 5.- Approach of Pilot#1A to K8.2 and K8.3

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g., robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Gorenje 1A is working on the robotic cells for manufacturing tubs. And this robotic unit will contribute to the KPI project indicator to achieve the proposed number of machinery where the RECLAIM technological solution will be implemented and demonstrated.	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
KP#1A.7 (Reference Gorenje) is linked to K8.3 and it will comply with that KPI of 8-10 years extension. Upgrade and refurbishment of robot cell equipment is necessary to improve machinery condition and to reduce unplanned machine failure, to reduce production and maintenance costs and to extend the machinery lifetime for further 15 years. Due to the project duration is difficult to measure this KPI.	

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4.1.2 Pilot #1B, Modernization and refurbishment of White Enamelling line

Table 6.- Approach of Pilot#1B to K2.1

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring
Currently, there are not so much physical inspections on the line but the parts identification and the new sensors to be applied on the robotic cells will help to this reduction but Gorenje thinks that could not be as much as 50% of cost reduction.	

Table 7.- Approach of Pilot#1B to K3.1.

K3.2	At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning
By this moment, Gorenje for this pilot is considering using this Toolkit but it will be evaluated the possibilities of the tool during the next iteration	

Table 8.- Approach of Pilot#1B to K4.4 and K4.5.

K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance
The parameter will be monitored from TPmer the internal application from Gorenje.	

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K4.5	Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)
The current maintenance efforts, MTBF is 2,5 days. Gorenje 1B can only obtain data from manual records of fails and maintenance efforts. With the refurbishment these records could be update automatically.	

Table 9.- Approach of Pilot#1B to K6.1.

K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
On the spraying cabin the failure are usually some blended spraying nozzles or hoses, which must be cleaned it take about 15 minutes, much less mistakes are due to high voltage fail, this kind of mistakes take more time.	

Table 10.- Approach of Pilot#1B to K8.2 and K8.3

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Gorenje 1B is working on the white enamelling line.	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
This KPI is related to KP#1B.7, so it will be evaluated directly on the pilot indicator.	

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4.2 Pilot #2 - Shoemaking Industry

Table 11.- Approach of Pilot#2 to K2.1

	**50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring**
Currently, there are not physical inspections, when some component fails it is repaired or in case, so the costs don't exist, but it will be an improvement on the components control and supervision.	

Table 12.- Approach of Pilot#2 to K3.1.

	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
By this moment, Fluchos is not considering using this Toolkit but it will be evaluated the possibilities of the tool on this pilot during the next iteration.	

Table 13.- Approach of Pilot#2 to K4.4 and K4.5.

	**Reduction of at least 20% of downtime due to unscheduled maintenance**
As there is no maintenance plan in Fluchos every action is an unscheduled maintenance, so the implementation of the new maintenance plan will achieve this percentage	

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<table>
<tr><td>K4.5</td><td>Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)</td></tr>
<tr><td colspan="2">Currently this parameter is not being measured, with RECLAIM it will be deployed a maintenance plan, but it could not be compared because the was not one before.</td></tr>
</table>

Table 14.- Approach of Pilot#2 to K6.1.

<table>
<tr><td>K6.1</td><td>20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report</td></tr>
<tr><td colspan="2">The current times for solve the failures are as follow:
▪ Talonadora:
1) Cooling: once every three months. Breakage of a capillary in the cold bulb, because of handling the aluminium lasts.
2) Last fixing: wear of the bronze ring and breakage of the fixing screw. It is necessary to dill and tap for a correct reparation.
3) Pneumatic system: once every three months everything must be checked, pressure switches, valves, etc.
4) Shutdowns are used for maintenance, cleaning condensers, revisions, greasing, etc.
▪ Rotostir:
1) Lasts: every day, resistors are melted. This is a problem for the temperature control which is currently controlled in open loop. However, when the machine is stopped, for loading or organization, the temperature increases under significant figures.
2) Rotary table: every four months, the clutch needs to be calibrated to guarantee the stop of each mould in the correct position. Every two years, reducers that allow the turning must be adjusted.
3) The fastening screw of the last is repaired in dead times between production in just half an hour.</td></tr>
</table>

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Table 15.- Approach of Pilot#2 to K8.2 and K8.3

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Fluchos is working on two machines: Talonadora and Rotostir so it will be accomplished.	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
This KPI is related to KP#2.5, so it will be evaluated directly on the pilot indicator.	

4.3 Pilot #3 - Woodworking Production

Table 16.- Approach of Pilot#3 to K2.1

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring
Currently, there is not any kind of monitoring or inspection activities. Quality control is only good's visual inspection by the operator of each process	

Table 17.- Approach of Pilot#3 to K3.1.

K3.2	At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning

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This KPI will calculate as follows: Maintenance cost per machine = Components/materials replaced costs + service contract + maintenance cost (both internal that external). Currently there is no data, but it is an ongoing activity for Podium to obtain them.

Table 18.- Approach of Pilot#3 to K4.4 and K4.5.

K4.4	**Reduction of at least 20% of downtime due to unscheduled maintenance**
We could consider the time to repair as the time to unscheduled maintenance, because Podium doesn't do maintenance planned except weekly cleaning and some operations.	
K4.5	**Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)**
Currently Podium has not any kind of maintenance management, so all efforts are used to repair/solve the failures of the machineries. On RECLAIM, PODIUM would like to implement the predictive maintenance (and so on), so the effort will increase for sure.	

Table 19.- Approach of Pilot#3 to K6.1.

K6.1	**20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report**
Maybe, the time to resolve a failure could be decreasing by preventing the tool's change.	

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Table 20.- Approach of Pilot#3 to K8.2 and K8.3

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Podium is working on its 2 machines (edging and drilling ones), so they accomplish with this KPI.	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
This KPI is directly related to one of the pilots, so it will be evaluated on that indicator, as Podium indicator is looking for an extension of 6/8 years, this KPI will be granted.	

4.4 Pilot #4 - Friction Welding Technologies

Table 21.- Approach of Pilot#4 to K2.1

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring
Currently, in a series production, the inspection effort is about 2 minutes per part for a simple workshop inspection and a volume of 10 parts.	

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Table 22.- Approach of Pilot#4 to K3.1.

K3.2	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
To be calculated after the Pilot demonstration activity based in the Pilot conclusions and results obtained.	

Table 23.- Approach of Pilot#4 to K4.4 and K4.5.

K4.4	**Reduction of at least 20% of downtime due to unscheduled maintenance**
By a better adaptability of the machine and by knowing the reliability of the machine. The current downtime is approximatively estimated in 4 hours if spare parts and trained staff are available. So maybe this reduction will be difficult to achieve on this pilot.	
K4.5	**Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)**
Up to 3 years. Currently these are the maintenance efforts: ▪ Daily: 5 Minutes ▪ Weekly: 30 Minutes ▪ Monthly: 40 Minutes Every 6 Month: 45 Minutes	

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Table 24.- Approach of Pilot#4 to K6.1.

K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
One Friction welding Machine	

Table 25.- Approach of Pilot#4 to K8.2 and K8.3

K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g., robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
One Friction welding Machine	
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
Our RMS401 machine served for about 10 years. After refurbishment, it will serve for another 10 years.	

4.5 Pilot #5 - Textile Manufacturing

Table 26.- Approach of Pilot#5 to K2.1

K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring

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Currently, there is not any kind of monitoring or inspection activities. There are some data on the SCADA system, but it is not use for inspection.

Table 27.- Approach of Pilot#5 to K3.1.

K3.2	**At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning**
Zorluteks is considering the use of this tool. It is expected that in the next months it would be a presentation for the pilots of the optimization toolkit into details. But for this moment it is very difficult to Zorluteks to identify a possible target value to achieve.	

Table 28.- Approach of Pilot#5 to K4.4 and K4.5.

K4.4	**Reduction of at least 20% of downtime due to unscheduled maintenance**
It could be considered the time to repair as the time to unscheduled maintenance, because Zorluteks do once a year a total maintenance and weekly cleaning operations.	
K4.5	**Maintenance effort required is decreasing at 50% (linked to Mean Time Between Failure)**
Currently, the maintenance procedure in the factory is made following the instructions of periodic maintenance (1 times/year) given by the machinery manufacturers and the active maintenance are implemented when the failure occurs. There is no predictive maintenance strategy implemented, so the maintenance is carried out without a strict and planned control.	

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Table 29.- Approach of Pilot#5 to K6.1.

	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report
This value currently is not being measure by Zorluteks because the maintenance team solves the problem as soon as possible without controlling the time that takes do it.	

Table 30.- Approach of Pilot#5 to K8.2 and K8.3

	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling, and finishing, friction welding machines and finally bleaching machines.
Zorluteks is working on the bleaching machine	
	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability
This KPI is directly related to KP#5.5 from the pilot, so it will be evaluated on the pilot indicator.	

4.6 Summary table of Pilots´ KPIs.

In this section a summary of the KPIs by Use Cases is presented as an overview of the previous sections. The KPIs impact due to the RECLAIM solution implementation partially or fully, will be measure during WP6 demonstration activities.

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Table 31.- Summary table of KPIs measurability.

KPIs	KPIs definition	Measurability					
		Pilot#1.A	Pilot#1.B	Pilot#2	Pilot#3	Pilot#4	Pilot#5
K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring	The calculation feasibility is under consideration. Some figures will come based on the results of the demonstration activities results.	Some estimations will come after the demonstration activities. It is expected to achieve the KPI value.	Difficult calculation of the KPI as a whole for the overall factory. Some calculation could be done at specific components.	The smart sensorial network is not demonstrated at this Pilot.	The smart sensorial network is not demonstrated at this Pilot.	Difficult to estimate because of the lack of historical data.
K3.2	At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning	Measurability is under evaluation.	Tool kit use is under evaluation.	The optimization tool kit is not considered for this Pilot.	Measurable	Measurable after Pilot demonstration activities.	Difficult to estimate from the machine point of view. From the production point of view, it will be analysed.

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K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance	This KPI will be calculated by Gorenje own tool.	This KPI will be calculated by Gorenje own tool.	Calculation will be available as soon as the Fluchos internal maintenance plan will be implemented.	Difficult to calculated due to the lack of maintenance plan.	Difficult to achieve this figure at this Pilot.	Measurable
K4.5	Maintenance effort required is decreasing at 50% (linked to MeanTimeBetweenFailure)	Difficult to estimate even if there are the support of the prediction tools.	It could be calculated automatically after the refurbishment of the machines during project activities.	Difficult to calculated because of the lack of historical data.	The predictive maintenance plan will be implemented internally at Podium. The lack of historical data made difficult this KIP calculation.	Difficult to be measured under the project timeline.	Difficult to be measured because the predictive maintenance plan is under development.
K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report	Not considered for calculation.	Difficult to estimated due to the multi-failures' complexity.	Measurability is under evaluation.	Measurability is under evaluation.	Measurability is under evaluation but for one machine (the overall factory is not considered).	Difficult to calculated because of the lack of historical data.

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K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g., robot cells, automatic production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling and finishing, friction welding machines and finally bleaching machines.	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability	Difficult to estimate during the project timeline.	Difficult to estimate during the project timeline.	Difficult to estimate during the project timeline.	Difficult to estimate during the project timeline.	Difficult to estimate during the project timeline.	Difficult to estimate during the project timeline.

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4.7 Understanding main RECLAIM KPIs into industrial production organization

At D2.6, it was presented the categorization of the RECLAIM KPIs into the general industrial Performance Measurement Systems. In this section, it is reported how these prioritised KPIs fall within the general industrial metrics categories. Moreover, the alignment between RECLAIM prioritisation and the external survey carried out at T2.1 and reported at D2.12 are shown at this section. Showing the confluence between the external industrial need and the prioritisation done at RECLAIM in terms of main KPIs to measure the technical solutions impact into the refurbishment and the re-manufacturing of machines and production line to avoid digital obsolescence.

The categorization of the RECLAIM KPI into the general industrial Performance Measurement Systems structure conducted into the following categories:

- General Project KPIs with the following subcategories:
  - ✓ General Results KPIs
  - ✓ Pilots
  - ✓ Transversality / Transference
- Industrial KPIs that could be applied to any manufacturing company of production plant with the following subcategories:
  - ✓ Safety
  - ✓ Quality
  - ✓ Employees satisfaction
  - ✓ Productivity
  - ✓ Productivity Management & Programming and
  - ✓ Planification

The K8.2 is focus on the project impact measurement. The most relevant measurable units for the project metrics are the number of machines where the RECLAIM technical solutions are being demonstrated. The demonstration of the RECLAIM solution into different industrial sectors and machines typologies show the universality of the project results and their huge future potential impact into the European industrial sector.

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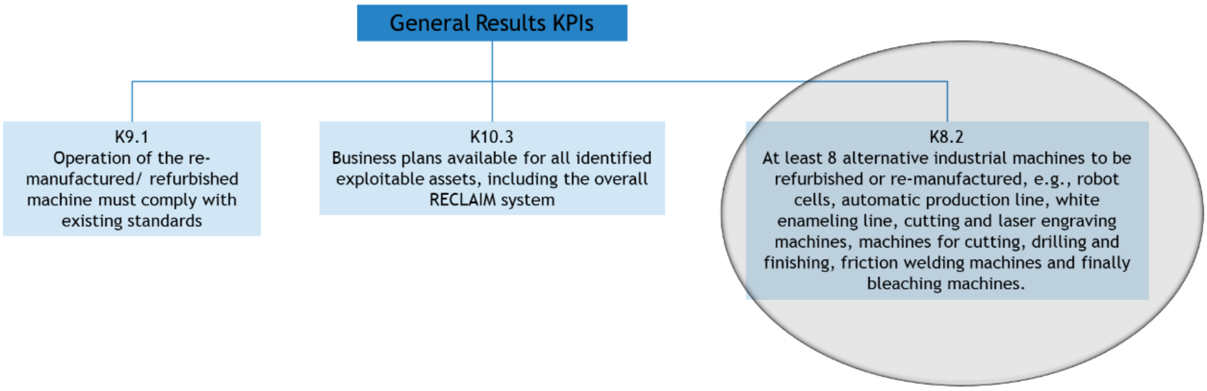

Figure 21.- K8.2 classification into the general.

From the Industrial KPIs that could be applied (Safety, Quality, Employees satisfaction, Productivity, Productivity Management & Programming and Planification) the prioritisation of the RECLAIM KPIs reflex that the most important metric are focus on productivity and planification. At the following figures the prioritised KPIs are highlight with a circle.

The development of technical solution to support the productivity increase and the planification of action in term of reparation, substitution or maintenance are the relevant topic to be covered by the refurbishment and re-manufacturing tools. These tools based in smart sensorial network, IoT communications and could computing digital tools will made enable the digitalisation of machines and process that otherwise will achieve their obsolescence, mainly in traditional sector where olds machines play a relevant role due to their unique characteristics or in machines with a quick obsolescence due to the market requirements. This finding has been confirmed at the D2.12 by the impact of the KPIs into each objective.

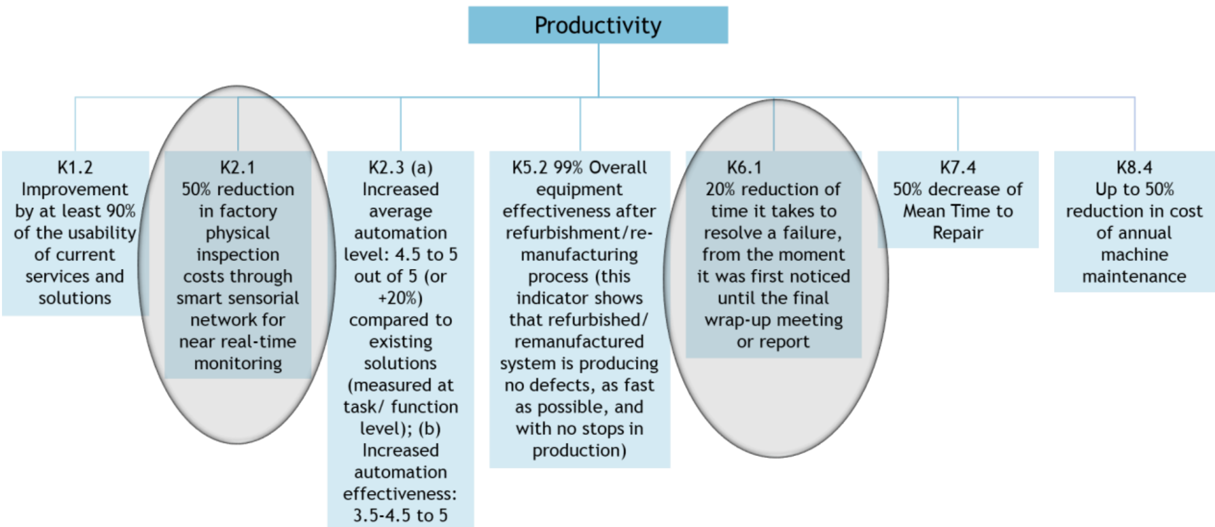

Figure 22.- Industrial Productivity KPIs with RECLAIM highlighted KPIs.

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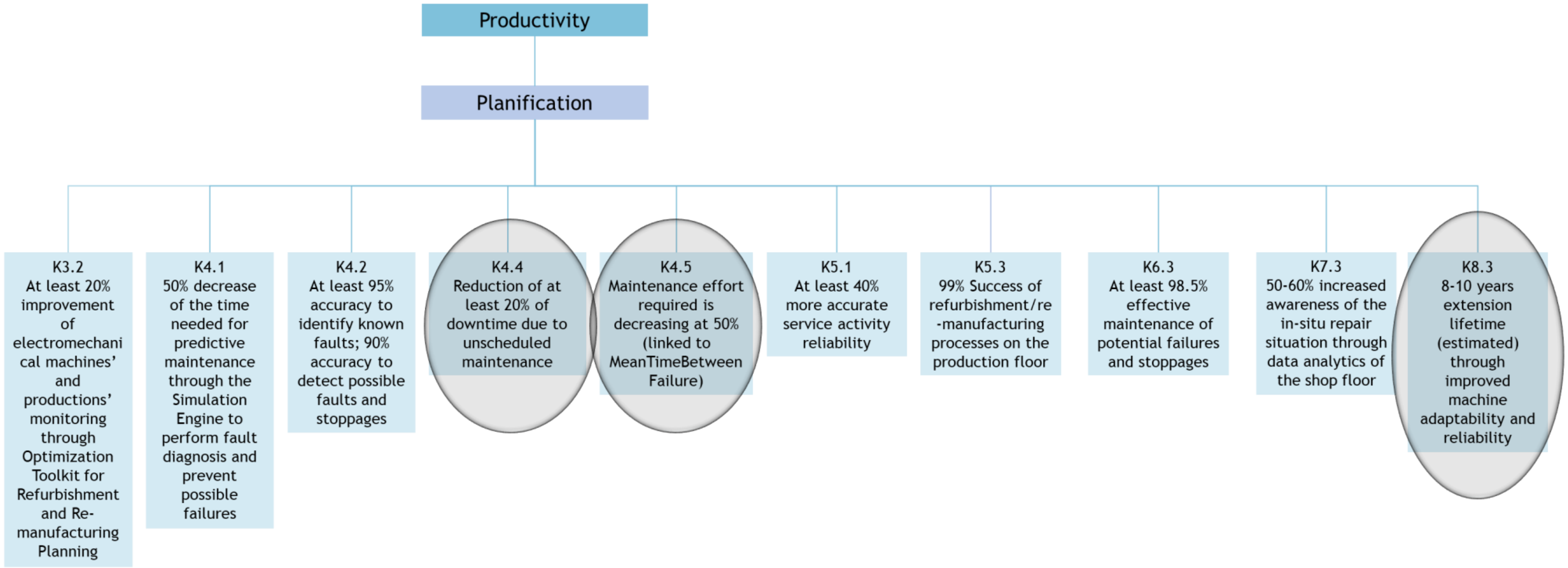

Figure 23.- Industrial Productivity focus on Planification KPIs with RECLAIM highlighted KPIs.

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5 Conclusion

The D2.7, RECLAIM Use Cases Definition & Operational Requirements #3 is the third iteration of the document, where the RECLAIM consortium present the most impacting KPIs for the measurement of the demonstration activities. The alignment without forgets the particular characteristics of each production lines from five different manufacturing companies really different but with a similar problem.

The prioritisation exercise reflects the relevance of the indicator lined with productivity and with planification, because of their direct impact in term of cost and time. The alignment of this KPIs, internally for the 6 Use Cases and externally with the industrial companies that answer the survey, confirm the correct selection of the indicators to guarantee the RECLAIM technical solutions future impact into the European industry. Highlight, that this impact increase even more, when the refurbishment and re-manufacturing solution is applicable to traditional sector that in risk of digital obsolescence, but where machines unique and irreproducible have to be operative and it is not possible to substitute guarantee the same level of product quality or machines where the high requirements allow them to a quick obsolescence.

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Annex A.- KPIs Listed on DOA

DOA_KPI ID	Title	Objective	WPs
K1.1	Fulfilment by at least 85% of user's requirements concerning lifetime extension methods in old machines (identified during the user requirement analysis)	O1	WP2 to WP7
K1.2	Improvement by at least 90% of the usability of current services and solutions	O1	WP2 to WP7
K1.3	Service aggregation from 4 toolkits through RECLAIM's single point of access, reaching up to 30% faster decision making about the best recovery strategy	O1	WP2 to WP7
K2.1	50% reduction in factory physical inspection costs through smart sensorial network for near real-time monitoring	O2	WP3
K2.2	80% accuracy in detection of machinery failures, possible malfunctions and stoppages based on historical operational data and data from smart sensorial network and life cycle status.	O2	WP3
K2.3	(a) Increased average automation level: 4.5 to 5 out of 5 (or +20%) compared to existing solutions (measured at task/ function level); (b) Increased automation effectiveness: 3.5-4.5 to 5	O2	WP3
K2.4	Continuous information sharing between manufacturers, maintenance services providers, industries, European Re-manufacturing Network etc. for best recovery strategy	O2	WP3
K3.1	20-30% increase of number of sensors which implement each pilot use case OR set up initial sensor set.	O3	WP3
K3.2	At least 20% improvement of electromechanical machines' and productions' monitoring through Optimization Toolkit for Refurbishment and Re-manufacturing Planning	O3	WP3
K3.3	At least 20% increase in data flow from the shop-floor to the DSF through Digital Retrofitting Infrastructure	O3	WP3
K3.4	Machine Health Index (=SUM (i:1...N) of Wi x Xi), where N: number of components in machine, i: sensing line, w: weight of component, x: the component level of sensing line) -- see formula at DOA	O3	WP3

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K4.1	50% decrease of the time needed for predictive maintenance through the Simulation Engine to perform fault diagnosis and prevent possible failures	O4	WP4
K4.2	At least 95% accuracy to identify known faults; 90% accuracy to detect possible faults and stoppages	O4	WP4
K4.3	Support effective maintenance process development	O4	WP4
K4.4	Reduction of at least 20% of downtime due to unscheduled maintenance	O4	WP4
K4.5	Maintenance effort required is decreasing at 50% (linked to MeanTimeBetweenFailure)	O4	WP4
K5.1	At least 40% more accurate service activity reliability	O5	WP4
K5.2	99% Overall equipment effectiveness after refurbishment/re-manufacturing process (this indicator shows that refurbished/ remanufactured system is producing no defects, as fast as possible, and with no stops in production)	O5	WP4
K5.3	99% Success of refurbishment/re-manufacturing processes on the production floor	O5	WP4
K6.1	20% reduction of time it takes to resolve a failure, from the moment it was first noticed until the final wrap-up meeting or report	O6	WP5
K6.2	20% reduction of cost of downtime during a failure incident	O6	WP5
K6.3	At least 98.5% effective maintenance of potential failures and stoppages	O6	WP5
K7.1	85%-95% satisfaction, with relation to technical aspects, of shop floor managers	O7	WP5
K7.2	50% reduction of days needed to complete all repairs	O7	WP5
K7.3	50-60% increased awareness of the in-situ repair situation through data analytics of the shop floor	O7	WP5
K7.4	50% decrease of Mean Time to Repair	O7	WP5
K8.1	Number of pilots in operational environments under the direct responsibility of the end-users involved	O8	WP6
K8.2	At least 8 alternative industrial machines to be refurbished or re-manufactured, e.g. robot cells, automatic	O8	WP6

	production line, white enamelling line, cutting and laser engraving machines, machines for cutting, drilling and finishing, friction welding machines and finally bleaching machines.		
K8.3	8-10 years extension lifetime (estimated) through improved machine adaptability and reliability	O8	WP6
K8.4	Up to 50% reduction in cost of annual machine maintenance	O8	WP6
K9.1	Operation of the re-manufactured/ refurbished machine must comply with existing standards	O9	WP7
K9.2	50% reduction in the number of incidents and failure-related accidents due to malfunctioning	O9	WP7
K10.1	Replicate RECLAIM's result to at least 3 other machines and production lines in pilot scenarios	O10	WP3 to WP8
K10.2	Number of future stakeholders/ providers more than 30	O10	WP3 to WP8
K10.3	Business plans available for all identified exploitable assets, including the overall RECLAIM system	O10	WP3 to WP8

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Annex A.- Objectives Listed on DOA

OBJ ID	Title	Addressed
O1	To devise and deploy circular economy strategies addressing the end-of-life issue of large industrial equipment, aiming to extend the lifetime of machines, improve performance and increase resource efficiency of heavy machinery.	WP2 to WP7
O2	To develop the appropriate tools and decision support methodologies for a) the inspection and assessment of malfunctions; b) the planning and preparation of the necessary refurbishment or re-manufacturing of large industrial equipment.	WP3
O3	To deploy an adaptive sensorial network and fog computing framework for near real-time monitoring of the machinery health status and the production line.	WP3
O4	To adapt and implement a simulation engine to perform fault diagnosis and predictive maintenance to contribute to effective damage repair.	WP4
O5	To optimise the planning of refurbishment and re-manufacturing activities & processes.	WP4
O6	To deploy novel HMIs for refurbishing/re-manufacturing large-scale electrical and mechanical machinery.	WP5
O7	To raise situational awareness through the in-situ repair process.	WP5
O8	To validate and demonstrate the proposed solutions through a set of real-life pilot sites.	WP6
O9	To ensure the safe and secure operation of the refurbished/ remanufactured equipment.	WP7
O10	To scale-up to other industrial environments through a virtual replication design.	WP3 to WP8

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