Total Resource and Energy Efficiency Management System for Process Industries

Deliverable 1.5

Lessons Learned and Updated Requirements Report

Date: 28/02/2017

WP1 Requirements Engineering

T1.5 Evolutionary Requirements Elicitation

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Executive Summary

The requirements elicitation in MAESTRI is carried out applying a user-centred approach (see D1.4 Initial Requirements Report for details). According to this approach, user workshops were carried out at each demonstration site where we interviewed employees involved in the processes that are relevant to the MAESTRI project. From those interviews and the deliverable D1.3 MAESTRI Business Cases we derived a set of functional and non-functional requirements. Within Task 1.5 (Evolutionary Requirements Elicitation) we went on to refine the level of detail of scenarios. The result of this work is presented in chapter 2. Based on the scenarios and on the work done in Task 5.1 (Architecture Design), D5.2 Final MAESTRI Platform Architecture Design & Specification, we have updated existing requirements and generated refined ones. They are presented in chapter 4.

As Task 1.5 evolves, the set of requirements will be updated and extended. D1.6 Lessons Learned and Updated Requirements Report will be based on D1.5.

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1 Introduction

1.1 Purpose, context and scope of this deliverable

The purpose of this deliverable is to give an overview of lessons learned and requirements update considering the time between project's start and M18. It is based on the first common source of user requirements for the MAESTRI consortium which was presented in D1.4 as well as on the first version of D1.5, v. 1.0 which was published in M14. Following the initial requirements elicitation, we planned on creating more detailed scenarios that would allow to derive further requirements from them.

As described in D1.4 the iterative process for the requirements management supports the continuous refinement of scenarios and the requirements which will be performed by the project partners.

1.2 Deliverable Organization

This deliverable is organized as follows:

- Chapter 2 describes 3 scenarios, namely the baseline calculation, ecoPROSYS© assessment, and MSM© improvement.
- Chapter 3 presents lessons learned.
- Chapter 4 contains an update on the list of requirements.

2 Scenarios

2.1 Introduction to the scenarios

The current set of scenarios is the first iteration on deriving more detailed scenarios highlighting aspects of the MAESTRI platform by also taking into account the peculiarities of the four pillars of the Total Efficiency Framework namely Efficiency Framework, Lean Management, Industrial Symbiosis, and IoT Platform. The IoT platform that will help achieving the MAESTRI Platform objectives is another important factor that had to be taken into account during the creation and refinement of the scenarios.

2.2 Scenario 1 – Baseline Calculation

Pedro is production manager at an injection moulding company. The company established goals to **continuously increase sustainability and resource efficiency**. Pedro got a challenging task, namely **to improve the efficiency and eco-efficiency of one of the main processes.** He decided to use the MAESTRI platform and, as a first step, he leverages the Eco Orbit View (EOV) [Pawlik E. et al. (2016)] methodology in order to analyse the company's business process and to be able to choose potential improvement areas and identify the **unit processes**[1] that compose the **production process** under analysis. Eco Orbit View (EOV) is a simple method intended to find out improvement areas within the

[1] Smallest element considered for which input and output data are quantified (e.g. Raw material storage; Raw material feeding system; etc.)

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production process where the company may want to simultaneously improve business and environmental performance. It is carried out in 5 steps according to D3.4 Training Materials:

1. Identify production unit processes (for a selected product family)
2. Identify Key Performance Indicators (KPIs) or Environmental Aspects relevant for each unit process
3. Identify Key Environmental Performance Indicators (KEPIs) relevant for each unit process
4. Identify links and synergies between KPIs and KEPIs
5. Prioritize improvement ideas, select potential improvement areas

Pedro is able to say that the company´s business process to be improved is composed of the following unit processes:

- Raw material storage
- Raw material feeding system
- Manufacturing Process
- Transportation to Quality Control conveyor
- Quality control
- Packaging
- Final product storage

This steps set the boundaries of the process under analysis.

Furthermore, thanks to Eco Orbit View results, Pedro has identified KPIs which can be used to assess the production process regarding quality, cost and service scope, from the company's point of view. The identified KPIs are the following:

Table 1 – Eco Orbit View Variables / KPI list outcome (from the company's collaborators/managers/workers point of view)

KPI	Target[2]	Current	Scope
Product A cycle time/shot [s]	16,30	16,35	Cost
Product B cycle time/shot [s]	9,00	9,10	Cost
Cooling water infeed temperature [ºC]	26	26	Service
Number of parts produced (total) vs. shift plan	97%	98%	Service
Number of rejects [NOK = Not OK cycles]	<3%	2,5%	Quality
Machine stoppages (without maintenance stops)	TBD[3]	TBD	Service
Maintenance planned stoppages [per shift]	1	1	Cost
Product A performance (easy open test passed) [2 samples per hour]	100%	99%	Quality
Product B calibration test [2 samples per hour]	100%	99,99%	Quality
Energy consumption per machine [kWh]	TBD[4]	TBD	Cost

[2] Target values were set by the company, during the EOV workshop, according to their experience and knowledge. The target values reveal the optimal values from the company's top management, middle management, and the operator's point of view, for the process to run.
[3] To Be Defined - Target and current values for machine stoppages have not yet been determined.
[4] To Be Defined – Target and current values for energy consumption per machine are still to be defined.

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The first contact between the MAESTRI team and the company was established, and enabled the MAESTRI team to better understand the business and the production process. The MAESTRI team is a team of experts in: i) identifying potential improvement areas; ii) identifying KPIs (reflecting company needs); iii) identifying KEPIs (reflecting environmental needs); iv) assessing process efficiency; v) assessing eco-efficiency performance through a life cycle perspective i.e. through Life Cycle Assessment (LCA) and Life Cycle Costs Analysis (LCC).

The analysis results in the indication of potential improvement areas, reflecting the needs of the company to improve both the economic and environmental performance (eco-efficiency). With this information, the MAESTRI team helps Pedro on the identification of process variables required to quantify/calculate the selected KPIs. In order to identify these variables, as well as to validate the selected KPIs to support decision making regarding the defined goals, they perform an **eco-efficiency analysis using ecoPROSYS©** tool and an **efficiency analysis using MSM©.** The goal is then to establish and define the current situation, i.e. baseline, of selected processes in terms of eco-efficiency (i.e. from economic and environmental performance point of view) and in terms of efficiency.

Pedro defines one complete production process cycle as the functional unit for the Total Efficiency Assessment before the actual data collection takes place. Pedro knows that cycle time of the production process is a critical aspect for the business, therefore he wants to evaluate the performance of each unit process per cycle.

The functional unit[5] is defined by the user and registered on the MAESTRI Platform, therefore Pedro defines the quantification of the identified functions (performance characteristics) of the production process. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of results, which is particularly critical when different processes are being assessed, since it is necessary to ensure that such comparisons are made on a common basis.

Thanks to the company's ICT expert André, Pedro knows that some of the identified variables can be retrieved from the production machines. More specifically, these variables are the following:

Table 2 - Data which can be retrieved from machines

Variable	Unit
Total energy consumption by production machine	kWh/cycle
Specific energy consumption during unit process 1	kWh/cycle
Energy consumption during unit process 2	kWh/cycle
Energy consumption during unit process 3	kWh/cycle
Specific energy consumption during unit process 4	kWh/cycle
Specific energy consumption during unit process 5	kWh/cycle
Specific energy consumption during unit process 6	kWh/cycle
Cycle time	s/cycle
Cycle time for unit process 1	s/cycle
Cycle time for unit process 2	s/cycle

[5] As defined in ISO 14040: https://www.iso.org/obp/ui/#!iso:std:37456:en

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Variable	Unit
Cycle time for unit process 3	s/ cycle
Cycle time for unit process 4	s/cycle
Cycle time for unit process 5	s/cycle
Cycle time for unit process 6	s/cycle
Planned downtime	min or hours / day
Unplanned downtime	min or hours / day
Total downtime	min or hours / day
Total time in use	min or hours / day
Number of stoppages	#
Number of stoppages due to lack of raw material	# and/or min or hours / stoppage
Number of stoppages due to machine maintenance	# and/or min or hours / stoppage
Mass or volume of material	g or mm^3/cycle (g or mm^3/part)
Total water consumption	l or m^3/cycle
Water infeed temperature	°C or K

André also told Pedro that the ERP system has lately been integrated through the MAESTRI IoT platform, and some other useful variables can be received from there (especially cost data related to the production process, financial data, e.g., GVA- Gross Value Added); the following variables are gathered:

Table 3 - Data which can be retrieved from ERP

Variable	Unit
Machine setup labour costs	€
Maintenance labour cost	€
Gross value added (GVA)	€
Earnings before interest, taxes, depreciation and amortisation (EBITDA)	€
Energy costs	€/kWh
Material costs	€/ton
Number of parts produced per time (cycle time)	# (number of cavities)
Planned downtime	min. or hours / day
Number of NOK cycles	# of NOK cycles / day or shift
Number of NOK parts	# of NOK parts / day or shift

After identifying these process variables for which the values were imported via the IoT platform into the MAESTRI Efficiency software, Pedro classifies them as deterministic[6] and non-deterministic[7]. As a next step, he identifies the "value added (VA) and/or the non-value added (NVA) actions. A NVA action does not change the product in any physical or chemical manner; a VA action does in turn change. Pedro is aware that it is not possible to clearly quantify the VA and NVA for deterministic variables. He must define a target ("set point") for VA or NVA instead, keeping in mind that it is possible to quantify the total value of the variable. For the definition of VA of non-deterministic variables, Pedro defines the minimum and maximum reference value/set point, for this case Pedro considers all events

[6] non-randomly behaved, e.g. material consumption
[7] randomly behaved, e.g. temperature, humidity

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that occur within the maximum and minimum reference value as contributing for VA and the other events as contributing for NVA.

After the finalization of these definition steps, the automatic data collection is performed by the MAESTRI IoT platform. The specified data for each cycle and for each machine is stored in the MAESTRI platform for later retrieval.

For the production process baseline calculation, process data collected in one week will be used. One week of data is considered by the company as being a representative time-frame. Pedro uses this data to define, in the total efficiency software, the set points, i.e. the set point for each variable within each unit process, using the data collected during one week and the knowledge regarding the theoretical/experienced assessment. After Pedro defines the set points, he opens the total efficiency software, and the respective GUI for ecoPROSYS© and MSM© modules to assess the eco-efficiency and efficiency, respectively. Thus, he calculates the baseline using the data collected during that week via the MAESTRI IoT Platform, and he attains reference results for both eco-efficiency and efficiency.

Pedro and his team are now ready to present the baseline results to the company management, namely the eco-efficiency ratios for the production process (e.g. total costs of the production process (€)/ total environmental influence of the production process(Pt)) and efficiency performance of the process. Pedro is able, for each variable, to compute the Unitary Efficiency Ratio (UEF) = VA/total, for the process, and subsequently quantify its efficiency.

2.3 Scenario 2 – ecoPROSYS© Assessment

Pedro launches the ecoPROSYS© module and accesses the energy material consumption per cycle (functional unit - one manufacturing cycle) for each unit process: mould closing, injection, cooling, and opening & extraction. He starts by running the performance assessment module of ecoPROSYS© where he classifies (1; 3; 5 scale) the intensity of each parameter to each eco-efficiency principle, i.e. his vision concerning how each process parameter influences the performance of the company regarding each eco-efficiency principle. As a result, ecoPROSYS© provides him a list of most suitable indicators' ratios to assess and characterise the process considering the problem and the goals.

The indicators' ratios suggested by ecoPROSYS© are shown in Table 4.

Table 4 – Set of indicators defined by Pedro to assess and present the results for the injection moulding process

Goal	Suggested Indicators
Pedro wants to avoid that the implementation of improvement actions on energy and material consumption affects the process productivity.	$\frac{Parts\ produced}{Energy\ consumption\ (kWh)}$ $\frac{Rejection\ rate}{Material\ consumption\ (kg)}$

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Pedro wants to assure that the implementation of improvement actions related to energy and material consumption of a certain process stage does not cause an increase of overall process environmental impacts.	$\frac{Energy\ consumption\ (kWh)}{Process\ total\ environmental\ influence}$[8] $\frac{Material\ consumption\ (kg)}{Process\ total\ environmental\ influence}$
Pedro wants to guarantee that the implementation of improvement actions on energy and material consumption results in the improvement of process eco-efficiency.	$\frac{Process\ total\ costs\ (€)}{Process\ total\ environmental\ influence}$

To assess and validate the suggested indicators' ratios, Pedro defines the goals for his assessment (as presented in table 4). To support the definition of these goals he looks at the available inventory that provides him information regarding the most energy-consuming operational phase. With this information Pedro validates the suggested indicators' ratios and proceeds with the eco-efficiency assessment.

On a given day, Pedro decides to use ecoPROSYS© so he gets the results and the defined indicators' figures based on online data and current energy and material consumption data. Based on these results he identifies several inefficiencies. He then identifies improvement measures and runs again ecoPROSYS© changing manually the energy and material consumption, considering the expected figures, i.e. estimation, resulting from the improvement actions. ecoPROSYS© presents a comparison between the stored results (with energy issues) and the improvement of energy and material consumption, in terms of costs, environmental influence, i.e., environmental impacts of energy and material consumed, and suggested indicators.

Pedro is now able to evaluate the eco-efficiency performance improvement potential for the defined improvement actions. Using the MAESTRI Platform, he shows to the management via the ecoPROSYS© GUI that the defined improvement actions do not affect process productivity and represents an actual decrease of process costs and environmental influence, and consequently an increase of the eco-efficiency performance of the process.

2.4 Scenario 3 – MSM© Improvement

In order to continue his assessment, Pedro launches MSM© module and sees the value-added vs. non-value added energy and material consumption for each unit process, i.e., in MSM© outcomes he accesses for each unit process the resource efficiency (VA/total) per variable (see Table 2), and also the aggregated resource efficiency which is determined by the average value of all resource efficiency values.

For operational variables, from the ERP, e.g. machine availability and amount of NOK parts; and from the injection machine e.g. temperature during injection for the machine line, he

[8] The *Process total environmental influence* is given by the sum of the environmental influence of all production unit processes considering energy and materials consumption as well as emissions and residues.

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can assess the operational efficiency. Pedro makes use of the *baseline feature* of the MAESTRI platform again.

Regarding the energy resource efficiency, he identifies several issues (inefficiencies), and he knows which unit process produces the most waste energy and can work on reducing the non-value added fraction of energy consumption. Similarly, to the eco-efficiency case (Scenario 2), Pedro can make a comparison using MSM© between the value-added vs. non-value added energy consumption, before and after improvements are implemented, this considering an estimation, resulting from the improvement actions potential gains.

In terms of efficiency assessment, according to MSM© principles, the following calculations are necessary:

- For each variable in each unit process, the fraction that adds value, and the fraction that does not add value must be clearly quantified. With these values it is possible to compute the **Unitary Efficiency Ratio (UER) = VA/total**
- The **Process Parameter Efficiency (PPE)**, of a specific variable, is calculated by the ratio between the total VA and the overall total (VA + NVA) that is placed in the system **(PPE =Total VA of the variable/Total VA + Total NVA).**
- The **Unit Process Efficiency (UPE)** is determined by average value of all efficiency values (UER within the unit process **(UPE = (∑UER/#UPE variables).**
- After quantifying the efficiency of all unit processes (UPE), it is possible to determine the **System Total Efficiency (STE)**. This indicator, STE, is determined by the average value of all UPE values.

3 Lessons Learned

LL-01 – The creation of homogenous scenarios taking into account four domains and the 4 pillars of the MAESTRI platform proved to be more complex than envisioned. It turned out that more time needs to be spent to identify the cross-sectorial aspects of the platform and to put them into scenarios before deriving requirements. This decision was taken in order to avoid wasting efforts by implementing components prematurely which would need to be rewritten later or would even require major changes to the system architecture. The reason behind was to enable us to develop components that are universal, easily adaptable and ultimately require less rework.

4 Updated Requirements List

Table 5 contains all MAESTRI requirements which are documented in JIRA and have been quality-checked (see D1.4 Initial Requirements Report for all details on requirement's workflow).

It is not yet decided which of these requirements are going to be part of specification (see D1.4 for details on requirement's workflow).

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Table 5 – List of Requirements

Requirement Key	Summary	Fit Criterion	Requirement Type
MAES-1	The platform will store the monitoring data permanently in order to access it later	Some monitoring will be stored permanently to permit advanced analysis. Those needs to be timestamped and the access to them should be provided by specific instrument (e.g. an API set or other approaches).	Functional
MAES-2	The system administrator can specify the time interval for monitoring the data in order to reduce the amount of data to be processed.	For every sensor the system administrator can specify the time interval for the measurement.	Functional
MAES-3	The MASTRI user can see and use data from existing systems without the need for manual data transfer	Data from relevant existing systems can be accessed through the interfaces provided by the MAESTRI IoT platform without the need to be manually inserted by users.	Functional
MAES-5	A user can export data in order to re-use it in other tools (e.g. for reporting)	MAESTRI provides an export function for calculated/monitored KPIs to text/CSV files, and an export function for an eco-efficiency and efficiency PDF report.	Functional
MAES-9	Downtimes of machines need to be recorded and analysed in order to optimize the machine-availability	The relevant monitoring data of each machine has been documented and the data is collected and stored accordingly.	Non-Functional -> operational
MAES-11	Access to forecasting data needs to be included in production planning in order to meet delivery deadlines.	Forecast data is accessible to the production planner either based on data coming from external sources or it is derived based on the analysis of the historic production data of the processes.	Non-Functional -> operational
MAES-15	The supply chain manager is able to analyze historical data about problems the supply chain in order to get decision support for future planning	Relevant historical data related to the supply-chain are collected. Historical plan and historical actual data will be compared and analyzed for deviations.	Functional

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		Statistical deviations are presented to the user.	
MAES-17	The production manager can simulate the fine-grain production scheduling in order to validate potential scheduling changes.	There is a simulation system through which a variety of production scheduling possibilities can be compared concerning their production capacity utilization figures. The higher capacity utilization can be determined using the simulation system.	Functional
MAES-20	Trainings on low-cost improvement methods are avalible for employees in order they know how to improve the eco performance	The training material is available.	Constraint -> scope of the product
MAES-21	The department manager can access a management board in order to check status of key performance and eco indicators	The user can access a management board and check for a given set of KPIs and eco indicators: values, chart with current trend vs. target value.	Functional
MAES-26	Existing suite of applications needs to better integrated in order to make them easier to use	80% of the functionality of the process systems functions are integrated in a unified Human Machine Interface (HMI).	Non-Functional -> usability
MAES-28	Reorder amount of raw material needs to be calculated automatically in order to reduce miscalculations	Calculating the reorder amount of raw material can be automated and the algorithm can be specified to match the companyÂ´s need.	Functional
MAES-29	Relationship between process variables and material properties need to be understood in order to support individualization of products to customer needs.	For 80% of the process variables used in the production process it is known how changes to material properties would influence the output qualities.	Non-Functional -> operational
MAES-32	Energy consumption must be monitored based on the process steps in order to find potential optimization steps.	Process energy consumed is monitored for all process stages in the processes under assessment.	Non-Functional -> operational
MAES-35	Management system supports eco improvements	Eco aspects are measured and eco improvements are conducted based on eco performance gaps	Constraint -> purpose
MAES-36	The current value of indicators related to	all indicators that have been identified by the	Functional

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	significant environmental aspects is visualized in order for everyone involved to be able to see and know the status	organization to be relevant for the improvement of processes are visualized and filled in with current data	
MAES-37	The training for an improvement method must include on the job training in order for employees to aquire practical skills	The training program for a certain improvement method includes on the job training.	Non-Functional -> performance
MAES-38	The training must include a follow-up in order to aid the participants with problems that may arise after first steps of method implementation	The training program for a certain improvement method includes follow-up.	Non-Functional -> performance
MAES-39	Eco aspects are integrated into the visualized performance measurement system	Eco indicators are equally visualized, updated and monitored as business KPI's.	Functional
MAES-40	The user can access a "how to see waste" guideline and get help on how to uncover waste streams in the company.	A waste manager will read the brief guideline and learn a methodology to identify waste flows in his company. The guideline will provide support regarding the implementation of the methodology.	Functional
MAES-41	The user can get support to characterise waste	Following the method detailed, the waste management team should be able to easily characterise waste at the right level of detail in order to enable the identification of suitable exchange opportunities.	Functional
MAES-42	The user get support to identify internal / external possible re-usability of waste	Following the method detailed, a waste manager should be able to identify possible uses of the company's waste, also using the waste database provided by MAESTRI.	Functional
MAES-43	Define the structure and contents for the standard efficiency and eco-efficiency reports	For each section of the standard PDF report a set of indicators and performance aspects has been identified and, these allow proper communication of the company processes in	Non-Functional -> operational

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		terms of efficiency and eco-efficiency performance.	
MAES-44	A manager can export a standard efficiency and eco-efficiency report	MAESTRI provides an export function for a standard eco-efficiency and efficiency PDF report	Functional
MAES-45	Visual mapping tools	MAESTRI, via DSS (see task 5.2), will encompass Visual Analytics engine presenting different state-related views of the production operations, supporting comparative assessment of material and resource management, enabling managers to visualise the entire process as well as each unit process and the respective inputs and outputs. Moreover, managers will be able to map the process (â€œprocess designâ€•).	Functional
MAES-46	Define the information and contents for the environmental footprint	The environmental footprint of each product belonging to a given set of products can be determined.	Non-Functional -> operational
MAES-47	The board and managers are able to define the companyâ€™s sustainability targets	For each company or site/plant a set of environmental and economic aspects and KPI has been identified and quantified, these allow the definition of the companyâ€™s sustainability targets.	Non-Functional -> operational
MAES-48	Definition of the simulation models for assessing scenarios	For each scenario, the efficiency and eco-efficiency performance has been quantified, these results allow the company to foresee the overall performance regarding a certain scenario.	Non-Functional -> operational
MAES-49	The production manager gets a prediction the best scenario in order to enhance overall efficiency and eco-efficiency	A forecast of the expected efficiency and eco-efficiency performance for different scenarios is displayed.	Functional

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MAES-50	Definition of the optimization models for energy and resources efficiency	The adoption of an optimization tool, will enable fast generation of optimized scenarios for improvement, since improvement scenario design optimization can be very time-consuming and unmanageable task a â€œtrial-error basisâ€•	Non-Functional -> operational
MAES-51	The production manager to perform optimization simulations and optimized scenarios for materials and energy consumption, via overall efficiency and cost-saving targets	A forecast of the expected optimized scenarios is displayed.	Functional
MAES-52	Prioritize options to support decisions for improvement measure (both cost-saving and efficiency improvements)	The major inefficiencies are identified and results are available, therefore the priority of each improvement action can be determined.	Functional
MAES-53	Definition of the LCA impact assessment methods and databases	Environmental impacts are evaluated according to selected LCA impact assessment methods and databases	Non-Functional -> operational
MAES-54	Perform Life Cycle Assessment	MAESTRI Platform provides a function for Life Cycle Assessment and user can calculate environmental impact	Functional
MAES-55	Definition of the Life Cycle Costing Analysis and Value Modelling approaches	Costs and value is evaluated for all process stages in the processes under research assessment	Non-Functional -> operational
MAES-56	Perform and evaluate Life Cycle Costing Analysis and Value Modelling	MAESTRI Platform provides a function for Life Cycle Costing Analysis and Value Modelling.	Functional
MAES-57	Managers can evaluate, through scenario analysis, the expected costs and perform simple payback analysis, considering the cost reduction and/or reduction of waste/missuses of resources	A forecast of the expected costs and a simple payback is displayed.	Functional
MAES-58	Develop models to identify and simulate appropriate consumption patterns and waste flows, leading to	A forecast of the expected consumption patterns and waste flows is displayed.	Functional

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	optimisation of materials and energy use via cost-saving optimization approach		
MAES-59	Real time metering, must be adopted to monitor energy and resource flows by adopting the Internet of Things (IoT) concept	The data collection is automated, so that the energy and resource consumption as well as other process related activities will be monitored in real time (or â€œnear real-timeâ€•).	Functional
MAES-60	MAESTRI platform needs to be defined in order to maximize the improvements in a single plant or across multiple companies, and enable more integrated and cross-sectorial interactions	A holistic approach will enable process monitoring and optimization, as well as focus on an integrated and cross-sectorial interaction that can have a greater impact within the process industry.	Non-Functional -> operational
MAES-61	The production manager is able to monitor, analyse and mine efficiency performance data in order to find inefficiencies (assess overall efficiency performance using MSM© analysis)	MAESTRI is able to analyse monitored data and to identify major inefficiencies regarding energy and resource consumption. MAESTRI presents the overall efficiency performance of a production system.	Functional
MAES-62	The production manager is able to monitor, analyse and mine eco-efficiency performance data in order to assess environmental and economic performance (assess overall eco-efficiency performance using ecoPROSYS©)	MAESTRI is able to analyse monitored data and to identify major environmental and economic impacts regarding energy and resource consumption. MAESTRI presents the overall eco-efficiency performance of a production system.	Functional
MAES-63	Plant managers are able to implement Maestri Platform gradually, since the Platform is scalable and flexible, concerning the scope of application (i.e. can be applied for production units, single plants, single companies or multiple companies)	The Maestri Platform is available and can be used to assess the overall efficiency and eco-efficiency of production units, single plants, single companies or multiple companies	Functional
MAES-64	Plant managers are able to assess Environmental	Most of industrial companies do not have significant environmental	Functional

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	Performance Evaluation (as defined by ISO 14031)	aspect indentified/defined for their processes neither certification on ISO 14001. Then, to ensure applicability of the tools on these cases, the MAESTRI platform (or its frontend applications) should provide assistance on defining significant environmental aspects. Standardised methods, namely ISO 14001, should be considered for this purpose.	
MAES-65	A clear approach needs to be outlined in order to define the value added and non-value added fraction, for each energy and resource flow in order to assess overall resource and energy efficiency	The Maestri Platform is available and can be used to Quantify the NVA of each stage of the process system	Non-Functional -> operational
MAES-66	Maestri Platform encompasses a methodology for modelling industrial processes, which includes resources and energy efficiency related aspects	Managers are able to perform model the process and consequently are able to perform optimization simulations	Non-Functional -> operational
MAES-67	Plant managers can use the Maestri Platform in order to create an overall efficiency index and company eco-efficiency profile	The user can evaluate on a monthly basis the efficiency performance and company eco-efficiency profile.	Non-Functional -> operational
MAES-68	MAESTRI's IoT platform should provide input data in order for ecoPROSYS© to calculate the eco-efficiency output	Relevant data for eco-efficiency assessment are accessible through at least one of the interfaces provided by MAESTRI IoT platform (e.g. REST API, MQTT, or other interfaces), as soon as it is made available from relevant data sources.	Functional
MAES-69	MAESTRI's IoT platform should provide input data in order for MSM© to calculate the efficiency performance output	Relevant data for eco-efficiency assessment are accessible through at least one of the interfaces provided by MAESTRI IoT platform (e.g. REST API, MQTT, or other interfaces), as soon as it is made	Functional

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		available from relevant data sources.	
MAES-70	Necessary data for Maestri Platform: Material flows and costs	Actual materials that make up the final product for a particular process (primary materials) and materials that are used in the processing of a product for a particular process. Materials may be non-renewable (i.e., materials extracted from nature that are non-renewable or stock resources such as coal), renewable, or flow resources such as water. Quantification, at each stage of the process system, of "what adds value" (AV) and "what does not add value" (NVA) to a product or service.	Non-Functional -> operational
MAES-71	Necessary data for Maestri Platform: Energy flows and costs	Process energy and pre-combustion energy (i.e., energy expended to extract, process, refine, and deliver a usable fuel for combustion) consumed and/or generated by any process in the business case. Quantification, at each stage of the process system, of "what adds value" (AV) and "what does not add value" (NVA) to a product or service.	Non-Functional -> operational
MAES-72	Necessary data for Maestri Platform: Water flows and costs	Water consumed and/or generated by any process within the business case, including effluents. Quantification, at each stage of the process system, of "what adds value" (AV) and "what does not add value" (NVA) to a product or service.	Non-Functional -> operational
MAES-73	Necessary data for Maestri Platform: Emissions to Air	Air outputs represent the releases to the environment of gaseous or particulates from a point or diffuse source of any stage of business case, after passing through	Non-Functional -> operational

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		emission control devices, if applicable.	
MAES-74	Necessary data for Maestri Platform: Emissions to water	Water outputs represent liquid surface and groundwater discharges, from point or diffuse sources of any stage of business case, after passing through any water treatment devices.	Non-Functional -> operational
MAES-75	Necessary data for Maestri Platform: Emissions to soil	Soil emissions represent discharges chemical substances that are considered pollutants to soil from point or diffuse sources of any stage of business case.	Non-Functional -> operational
MAES-76	Necessary data for Maestri Platform: Wastes	Represents the mass of a product or material, either solids or liquids, that are deposited as hazardous or non-hazardous waste, either before or after treatment (e.g., incineration, composting), recovery, or recycling processes. Quantity/volume of waste as well as route/treatment.	Non-Functional -> operational
MAES-77	Necessary data for Maestri Platform: Intermediate Products	Products or substance outputs from a process that are received as input by a subsequent unit process within the business case, enabling managers to keep track of the intermediate products.	Non-Functional -> operational
MAES-78	Necessary data for Maestri Platform: Equipment data and cost	Includes data on equipment used in the different processes within the business case, working related costs, including amortization, opportunity cost, etc.	Non-Functional -> operational
MAES-79	Necessary data for Maestri Platform: Labour cost	Direct and indirect (benefits and payroll taxes) labour costs	Non-Functional -> operational
MAES-80	Necessary data for Maestri Platform: Maintenance Activities and Costs	Maintenance activities schedule and costs related to any process and/or equipment or infrastructure used in a process within the business case.	Non-Functional -> operational

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MAES-81	Production system unused materials, energy and resources should be quantified	The aim is to exploit possible synergies with other production systems, as well as to incorporate the identification exercise into the daily routine of decision making in every company.	Non-Functional -> operational
MAES-82	Environmental performance evaluation should be used for simulation	the view of the company and the way it understands the production system should be included in scenarios simulation.	Functional
MAES-84	The production manager selectes a KPI in order to monitor it	The production manager is able to select KPIs that will be monitored by the MAESTRI platform.	Functional
MAES-85	The production manager is able to connect a KPI with a data source in order to monitor that KPI	The production manager is able to connect KPIs to a data source.	Functional
MAES-86	MAESTRI Platform user should be able to select the significant environmental aspects.	MAESTRI frontend applications user is able to select high environmental significant aspects.	Functional
MAES-87	The MAESTRI platform should be able to present the environmental impact related to each environmental aspect	MAESTRI platform user is able to import or calculate the environmental impact related to each environmental aspect by using the frontend applications	Functional
MAES-88	The MAESTRI platform user should be able select eco-efficiency ratios.	MAESTRI frontend applications user is able to select a limited number of eco-efficiency ratios.	Functional
MAES-89	The MAESTRI platform should provide assistance on defining eco-efficiency ratios.	MAESTRI frontend applications user is able to define eco-efficiency ratios.	Functional
MAES-90	The MAESTRI platform user should be able select different methods to quantify environmental influence, damage and impacts.	MAESTRI frontend applications user is able to define different methods and categories to assess environmental performance.	Functional
MAES-91	The MAESTRI platform user should be able assess/monitor the environmental influence considering cradle-to-gate or gate-to-gate analysis.	MAESTRI frontend applications user is able to select different scopes for environmental influence calculation.	Functional

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MAES-92	The MAESTRI platform user should be able to assess the intensity of each process/parameter/aspect to each eco-efficiency performance.	MAESTRI frontend applications user is able to assess the intensity of each process/parameter/aspect to each eco-efficiency principle.	Functional
MAES-93	The MAESTRI platform user should be able to perform sensitivity analysis to the results.	MAESTRI frontend applications user is able to perform sensitivity analysis of the results.	Functional
MAES-94	The MAESTRI platform user should be able to simulate changes in the process and create alternative scenarios.	MAESTRI frontend applications allows simulation and creation of "what if" scenarios.	Functional
MAES-96	The MAESTRI platform should be able to present different KPIs and eco-efficiency ratios results according to the different needs of the different level of the organisation	It is possible to select and show different efficiency and eco-efficiency results for shop floor and management	Functional
MAES-97	The MAESTRI platform should allow an integrated/simultaneous analysis of efficiency and eco-efficiency - Total Eefficiency Index	User is able to quantify TEI	Functional
MAES-98	Database of LCA module should be periodically updated.	User has the possibility to have updated LCA database	Non-Functional -> maintainability
MAES-99	Defined KPIs, eco-efficiency ratios and efficiency performance should be calculated using company's own data.		Functional
MAES-100	MAESTRI platform user can introduce manually data related to the process	User is able to manually input data	Functional
MAES-101	MAESTRI Platform user should be able to define targets for efficiency assessment	MAESTRI frontend applications allows target setting via manual data insertion.	Functional
MAES-102	MAESTRI Platform user should be to assess the environmental influence related to VA and NVA portions	MAESTRI frontend applications allows user to quantify the VA and NVA environmental influence	Functional
MAES-103	MAESTRI Platform user should be able to visualise MSM© efficiency dashboards	MAESTRI frontend applications show the efficiency dashboards	Non-Functional -> look and feel
MAES-104	MAESTRI Platform should not allow efficiency values over 100% (MSM©)	No efficiency values over 100%	Functional

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MAES-105	MAESTRI Platform should enable the user to consecutively aggregate the efficiency performance and eco-efficiency	MAESTRI frontend applications allows user to calculate efficiency and eco-efficiency of, for instance, a plant by integrating the results of the several production lines	Functional
MAES-106	"The MAESTRI Platform should be able to model business processes using Business Process Based Monitoringto monitor relevant process variables"	MAESTRI frontend applications allows user to model the process	Functional
MAES-107	The MAESTRI Platform should be able to map data coming from sensors and production systems to process steps	Process can be monitored in real-time and the data can be used for a more detailed analysis	Functional
MAES-108	The MSM© should be able to assess resource and operational efficiency	Assess the efficiency operational and resource efficiency	Functional
MAES-109	The MAESTRI platform should be able to provide GUI/dashboards, containing KPI's/information resulting from the IoT platform, MSM©, ecoPROSYS© or Efficiency Framework		Non-Functional -> usability
MAES-110	IoT platform should be able to process data	Provide process "raw data" to user (e.g. cycle time s/cycle)	Functional
MAES-111	MAESTRI Platform user should be able to assess the costs related to VA and NVA portions	MAESTRI frontend applications allows user to quantify the VA and NVA costs	Functional
MAES-112	MAESTRI IoT Platform has to provide access to EUROMAP 63 data	Recorded data from the Euromap63 interface is provided as event (e.g. by MQTT) and stored in permanently in a datastore. Both the event data and the historical data should be provided by a webservice interface.	Functional
MAES-113	The user can access a waste database in order to find out what similar companies (i.e. companies with the same NACE code) have done to implement Industrial Symbiosis	Entries in the database are classified according to the NACE codes of the companies taking part to the exchange, so the user can enter it with his/her NACE code and find exchanges implemented by similar companies.	Functional
MAES-114	The user can access a waste database where	The database has a "Use" field for each entry	Functional

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	he/she can find what kind of material might be suitable to his purposes and what kind of company might be a supplier.	allowing the companies to look for a specific use and therefore to exctract information regarding the materials used in each case.	
MAES-115	The user can link the relevant flows he/she has individuated in the waste database to the corresponding case studies in the library of case studies.	A unique numerical ID is assigned to each case and to each source in the library of case studies, and those IDs are recalled for each flow in the waste database, so that the user can always easily identify them.	Functional
MAES-116	The user can access a library of case studies to gather ideas on how Industrial Symbiosis has been implemented and how it worked in different case studies.	The library of case studies contains information regarding different Industrial Symbiosis implementations involving companies from different industrial sectors.	Functional
MAES-117	The user can search the library using keywords related to his/her country, main challenges in resource efficiency and barriers to overcome.	The user can keyword search the country, challenge or barriers in the library of case studies and find corresponding cases, from which he can extract related information.	Functional
MAES-118	The user can link relevant cases he/she has individuated library of case studies to the original sources, in order to find out more.	The user can use the link provided in the library in order to find the original source of data.	Functional
MAES-119	The user can send comments and suggestions regarding the library of case studies and waste database structure and contents to the data owner.	After accessing the library/database, the user is automatically redirected to a comments/suggestions form.	Non-Functional -> maintainability
MAES-120	The user can send his/her own Industrial Symbiosis case and waste flows to the data owner, in order to be added to the library of case studies and waste database.	After accessing the library/database, the user is automatically redirected to a "Send us your own case/waste flows" form.	Non-Functional -> maintainability

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