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MOdel based coNtrol framework for Site-wide OptimizatiON of data-intensive processes

D7.2 – Final evaluation framework

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Executive Summary

This document aims at providing the final specifications for the MONSOON evaluation framework; this is a set of KPIs that allows to quantify the benefits of the application of data-driven optimization methodologies from several perspectives (environmental, industrial, cross-sectorial). This deliverable is the follow-up of D7.1 – Initial Evaluation Framework published at month 18 of the project.

A brief introduction gives the overview of the document, as well as basic information about the context. Focus is set on the rationale behind the evaluation framework, providing a detailed description of its purposes, its structure and the selected classes of KPIs.

Chapter 3 contains information about aluminium domain. For the relevant business cases, the most significant domain-specific KPIs are listed and explained. The same approach is adopted in Chapter 4 concerning plastic domain.

In Chapter 5, outcomes from the analysis of both domains are merged. A multilayer structure is defined for the evaluation framework: a base layer which contains cross-sectorial KPIs shared by both domains and a customized layer where domain-specific KPIs are stored.

Chapter 6 contains information about KPIs which can be used to evaluate replicability and scalability of the MONSOON platform from infrastructural point of view.

Chapter 7 provides considerations and comments about the Evaluation Framework in its final version. Upgrades from the initial version are reported and some final outcomes support further developments of this component towards an extensive application of MONSOON methodologies in process industries.

An example of environmental KPIs computed by MONSOON is available in the ANNEX: Example of environmental KPIs.

The ANNEX: Operating procedures and training material developed for the Dunkirk plant contains an extract of the configuration procedures for data analysis dashboards in the demonstrator plant of Dunkerque.

1 Introduction

This document is the second output from task 7.1 in the MONSOON project. The task is part of WP7, which is devoted to identifying tools to evaluate the effectiveness of the application of data-driven optimization methodologies developed by data scientists within other tasks of the project.

Goal of this document is to present the final specifications for the evaluation framework. This component is made of a collection of KPIs, clustered in different sections according to the nature of each of the selected indicators; with such a division, the evaluation framework allows to quantify the benefits from several perspectives, from the environmental one to the process one, including some considerations about scalability and replicability of the platform in different domains.

This deliverable describes the Evaluation Framework (EF) according to project status at month 30. Focus is set on developments and upgrades from initial version, with particular care for high-level KPIs which allow to evaluate the scalability and exploitability of the MONSOON platform. To avoid unnecessary repetition of information, for the full description of the EF and the rationale behind it, please refer to [RD.4].

The KPIs included in the EF are classified into different clusters to better address the evaluation of the platform according to the chosen perspective:

- ***Domain-specific KPIs***: this class includes all the indicators that are used to quantify the onsite effectiveness of the optimization functions. As a general consideration, these KPIs can't be cross-sectorial due to their high connection with the specific use cases and cannot be transferred to other domains (unless in case of particular conditions of technological similarity);

- ***Environmental KPIs***: this class includes all the indicators employed to quantify specific environmental impacts. These figures are used to quantify either the local and the global footprint related to the investigated process; typical examples of environmental KPIs are the total greenhouse gases emission, the use of resources, water consumption. These KPIs present high cross-sectoriality, as they can be used to evaluate the environmental impact of a wide range of manufacturing processes;

- ***Replicability KPIs***: this class includes aspects which are not related to the process but to the MONSOON platform itself. As one of the goals of the project is to provide a toolkit which can be adopted to boost efficiency in the process industry, the easiness of deployment of the platform should be carefully evaluated to ensure a market breakthrough.

Next chapters describe the selected use cases for aluminium and plastic domains that have been used to feed the evaluation framework during iteration 2[1]. For each use case, a brief description of the process-specific KPIs is presented. After these domain-specific analyses, a complete map of the selected KPIs will be presented in chapter 4, along with some considerations regarding the nature and the rationale behind each of the selected indicators.
Moreover, additional details of predictive models continuous analysis of real time data with instant feedback on the optimum conditions and potential impact have been detailed and addressed in D5.6 in Section 4 where the plugin in detailed in real time deployment.

[1] MONSOON adopts an iterative approach to deploy components and validate algorithms. According to this approach, the term "iteration" defines the two halves of the project; along this document "iteration 2" will identify the last period (M18-M36)

2 Related documents

ID	Title	Reference	Version	Date
[RD.1]	Initial Runtime Container	D 3.7	1.0	2017-11-30
[RD.2]	Initial Life Cycle Management plugin	D 5.7	1.2	2017-12-22
[RD.3]	Initial Online and deep machine learning techniques	D 5.3	2.2	2018-01-08
[RD.4]	Initial Evaluation Framework	D 7.1	1.2	2018-03-28
[RD.5]	Training material for Dunkirk plant		1	2019-08-22

3 Aluminium domain

This chapter describes the use cases selected for iteration 2 in the aluminium domain. A description of the process is provided, as well as some specifications related to the nature of the process KPIs.

3.1 Identified business cases

3.1.1 Carbon area

Carbon area has been analysed during iteration 1. Due to the large impact of anodes in aluminium production efficiency, further investigations occurred during iteration 2.

Anodes affect significantly the quality of the aluminium produced in the electrolysis pot; therefore, bad quality anodes may have a major impact on aluminium production cost. By reducing the variability and improving the control of the anode quality, it is possible to anticipate a decrease of the anodic incidents in the electrolysis pot (in particular, anode effects and mushrooms).

The anode assembly (called from now on along the document *anode*) that is introduced in the pot is the final product of the carbon area. This area is divided in 3 main workshops which have specific functions:

- The paste plant produces green anodes from calcined petroleum-coke, coal-tar pitch and recycled scraps and anode butts by mixing, forming and vibrocompacting;
- These green anodes are baked to obtain the mechanical and electrical properties of the anodes sought for the electrolysis reaction. This step is realized in the baking furnace;
- Finally, the baked anodes are sealed to metallic stem in the anode rodding shop to form the said anode assembly.
- Figure 1 represents the process flow to produce green anodes ready for electrolysis line:

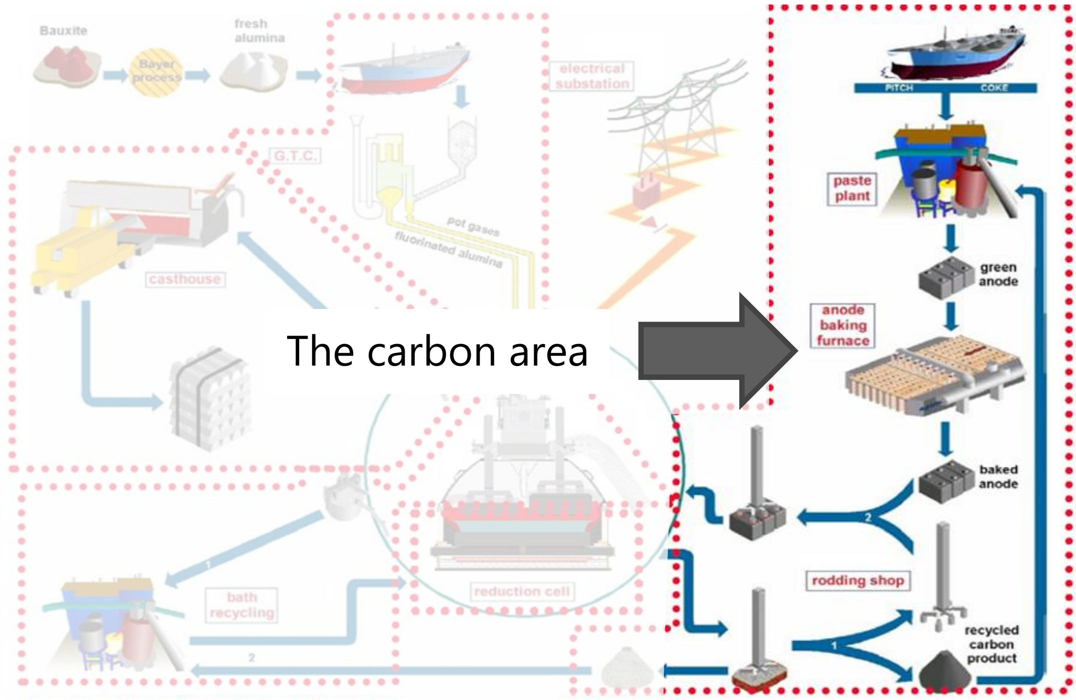

Figure 1 – The carbon area

The anode quality is greatly influenced by the variability in equipment running settings and their stoppages. Some relations between equipment settings variation, raw material recipe and anode quality are already known. But some are not yet discovered and need to be controlled.

During the first iteration of MONSOON, focus was set on the green anode production process as illustrated in Figure 2. The MONSOON project will help, thanks to the developed predictive functions, to understand the real-time impact of the equipment deviation from nominal setting or of the process parameters variability on the green anode quality and, when possible, trigger alerts to implement the correct settings or conditions to obtain the desired anode quality.

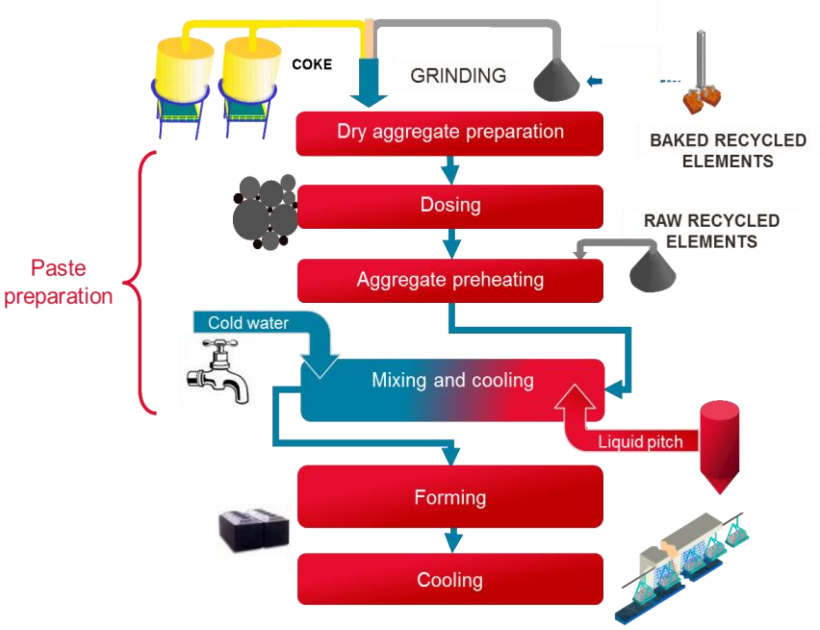

Figure 2 - Anode production process

During the first half of the project, about 50 relevant process variables, coming from onsite monitoring equipment of the machines of the chain depicted in the flowsheet diagram have been identified. These inputs were used to predict the anode density that is one of the most relevant KPIs defined for this use case (see 3.2.1).

3.1.1.1 Outcomes of the predictive models in the anode plant

An online module for optimizing Anode Quality was deployed at Dunkerque's plant. It aims at giving **explanations** and **recommendations** to the Paste Plant process engineers about periods of production for which the density is lower than usual. The recommendations are a list of three actionable parameters to be modified, and the values they should take (under several process constraints), in order **to maximize the anode density.**

The Anode Quality function is split in two separate modules: an **execution** module, that applies the machine learning models to the latest 30-minutes period, and generates explanations and recommendations in case of detection of an 'improvable' period; and a **training** module, that regularly re-trains the models based on the latest available data.

A dedicated Grafana User Interface was developed for allowing the end-user to visualize the results of the function. This interface is divided into three dashboards: the main dashboard, "Anode Quality Monitoring"; the "Histograms" dashboard, allowing further data visualization; and the "Performances Monitoring" dashboard, which gives information about the performances of the module. Some illustrations of those dashboards are shown below, with some information hidden for confidentiality purposes.

The "Anode Quality Monitoring" displays the following information:

- A global overview of the statuses of the last hours in terms of anode quality (Figure 3). The 'improvable' periods appear in red in the table; while the 'good' periods are in green. The periods where the Paste Plant was not working are displayed in blue;
- The "explanations" of lower anode quality obtained with the explanation module. They consist in a list of 5 process parameters, displayed in a table (Figure 4) for periods of 'improvable' quality that were detected as such by the model;
- The recommendations for improving the anode density, generated by the recommendation module. They are also displayed in a table (Figure 5).

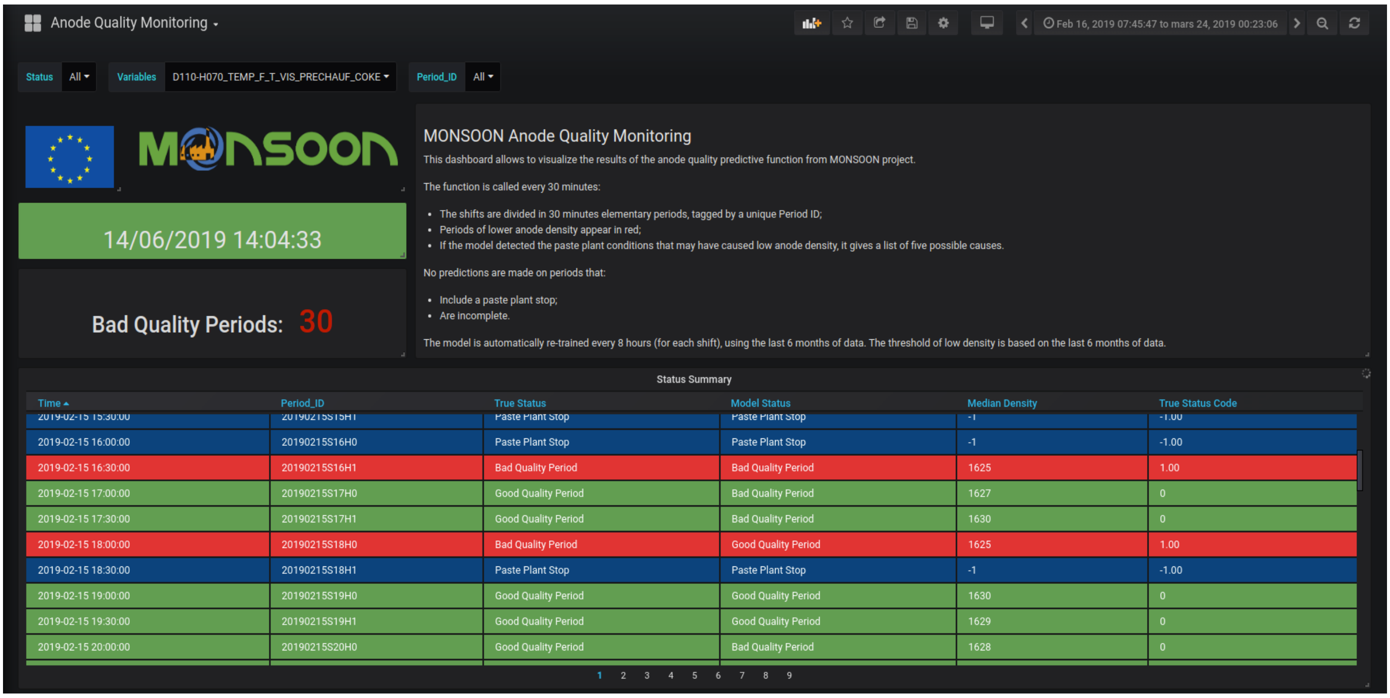

Figure 3: Anode Quality Monitoring dashboard – Overview

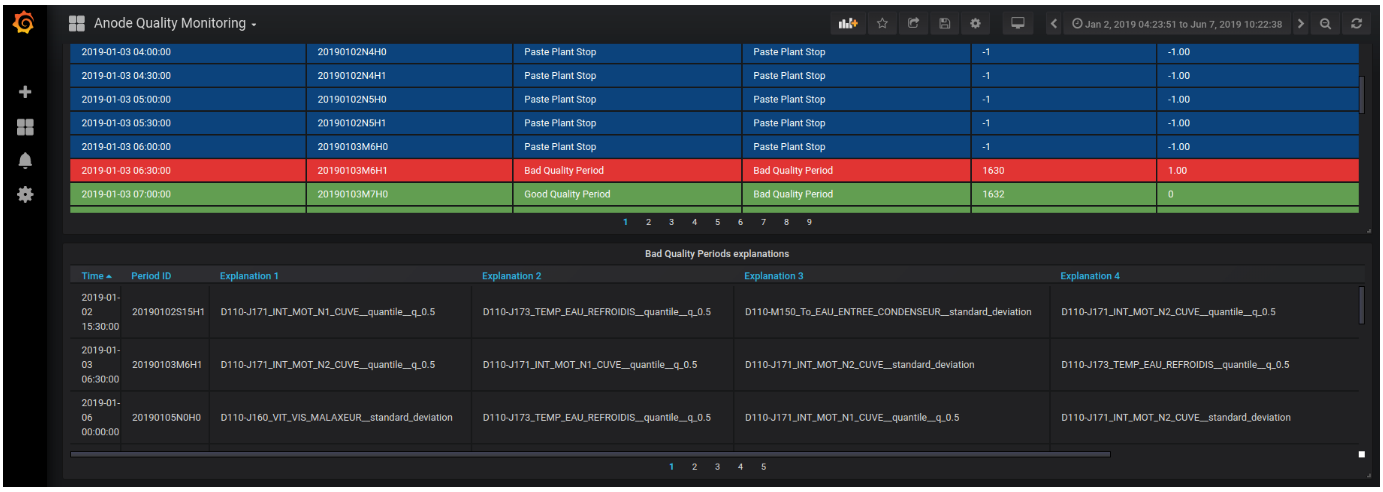

Figure 4: Anode Quality Monitoring dashboard - Explanations Table

Recommendations for density improvement

Time ▲	Period ID	Density	Target	Actionable 1	Reco. 1	Actionable 2	Reco. 2	Actionable 3	Reco. 3	Error
2019-02-01 08:00:00	20190201M8H0	1622.00	1629.31	H030_TEMP_RETOUR_F_T	[illegible]	J160_INT_MOY_MALAXEUR	[illegible]	J160_TEMP_PATE	[illegible]	5.18
2019-02-01 08:30:00	20190201M8H1	1623.00	1629.78	H070_TEMP_F_T_VIS_PRECHAUF_COKE	[illegible]	H030_TEMP_RETOUR_F_T	[illegible]	J160_TEMP_PATE	[illegible]	3.96
2019-02-01 09:00:00	20190201M9H0	1625.00	1630.53	H030_TEMP_RETOUR_F_T	[illegible]	J160_INT_MOY_MALAXEUR	[illegible]	J160_TEMP_PATE	[illegible]	2.46
2019-02-01 09:30:00	20190201M9H1	1624.00	1631.60	H030_TEMP_RETOUR_F_T	[illegible]	J160_INT_MOY_MALAXEUR	[illegible]	J160_TEMP_PATE	[illegible]	4.61

Figure 5: Anode Quality Monitoring dashboard - Recommendations Table

The recommendations given by the model show that improvements of up to 10 (i.e. density going from 1620 to 1630) on the density could be reached by adjusting the process parameters in an optimized way, as proposed by the anode quality function.

3.1.2 Electrolysis area

Electrolysis is the area where the production of aluminium takes place. The electrolytic pot is charged with alumina and a protective coating (the *bath*), then the anode is inserted and current flows through the equipment. By chemical electrolysis of primary material, liquid aluminium is created and collected when the process is over. This area is responsible for significant energy consumption, as the current intensity required to run the process is quite high.

Nowadays, the liquid heights (bath and metal) and the pot temperature are measured only every 32h (in most smelters, based on the electrolysis organization cycle). Between two measures, there is no clear knowledge of those variables. It is known that those variables have a great impact on the pot performances reflected by optimized energy consumption and current efficiency.

The illustration in Figure 6: Breakdown of the energy consumption for the aluminium production, i.e. the thermal balanceFigure 6 depicts the thermal balance of a pot. The major part of the energy consumed produces heat that is useful to maintain the temperature of the pot needed for the electrolysis reaction. Nevertheless, a large part of this heat is lost; proper control of these losses would allow to significantly increase process efficiency.

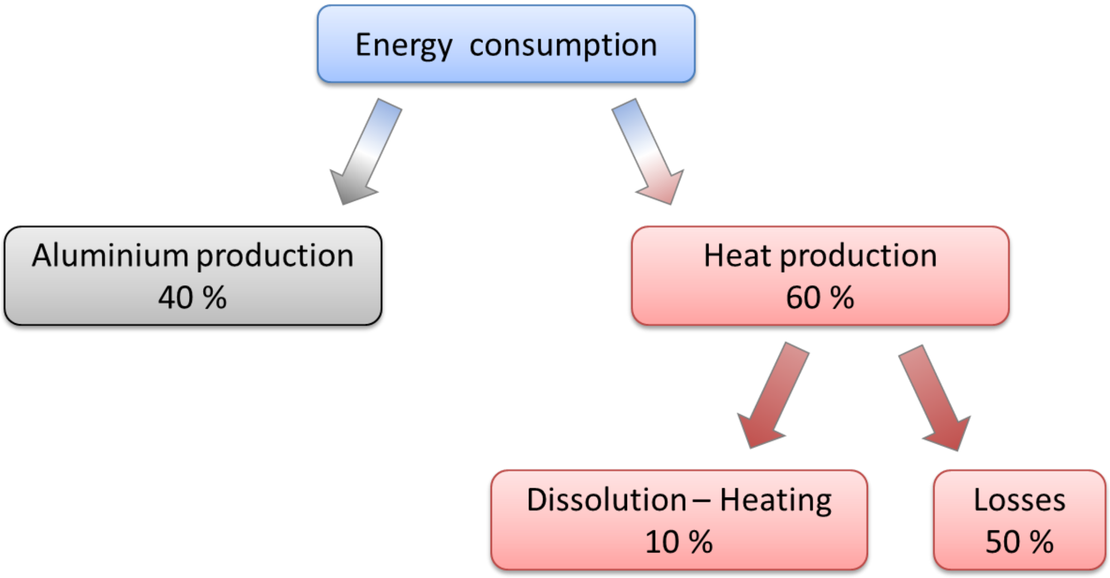

Figure 6: Breakdown of the energy consumption for the aluminium production, i.e. the thermal balance

The liquid heights may influence the bath chemistry, which must be kept in standard ranges in order not to reduce the pot current efficiency, which is directly linked to productivity.

The initial objective was to predict the liquid heights and eventually the pot thermal status based on the information given by the chisel-bath contact system (one piece of equipment of the pot), thanks to the predictive functions that have been developed during MONSOON iteration 2.

However, the Aluminium Pechiney (AP) expert team launched an internal project in order to work on the prediction of the metal height. The scope of the business case 2 is therefore refocused on the bath height and thermal pot analysis from now on.

The first objective is to give an estimation of the bath volume contained in the pot, based on historic data, and then validate this approach looking at real time data.

Prediction of the thermal balance in the pot represent a promising improvement which might be investigated during the follow-up of MONSOON.

The final target is to:

- Give indications on the appropriate operations to be done on the pot in order to adjust the bath volume
- Give optimal parameter settings based on process expertise

The second objective is to anticipate process deviations via predictive alerts and take countermeasures (e.g. adjust parameters settings) to improve pot stability.

When a variation is discovered, sometimes after anode incidents or pot instability, adjustments are made on:

- Anode/Cathode distance (ACD), impacting the current efficiency

- Adjustments of the bath (volume and chemistry)

This scenario is foreseen as a process optimization scenario. In the following paragraphs an overview of the involved phenomena is reported; KPIs associated to the process are described in further sections of the document.

3.1.2.1 Bath height

It is well known by electrolysis process experts that the bath volume impacts the alumina dissolution. If the bath height is too low the alumina dissolution will not be optimized; this may lead to decrease in technical performance (current efficiency). If the bath height increases, the bath may completely submerse the anode and may attack the pins of the anode, leading to metal pollution (with iron).

On the other hand, if the bath height decreases, it may provoke the covering bath to collapse into the liquid bath and so modify the bath chemistry and the insulation properties, leading to pot perturbation and anode consumption acceleration (due to reaction with the surrounding air).

3.1.2.2 Thermal balance

The pot temperature must be kept between ranges in order to prevent the phenomena depicted hereunder:

- If the temperature rises, the bath chemistry changes, which might lead to pot instability (and anode effects) and to a decrease of aluminium production due to re-oxidation of the aluminium.
- If the temperature decreases, the cryolite contained in the bath may solidify preventing the alumina dissolution and creating sludge at the bottom of the pot. This must be avoided to ensure a proper movement of the liquid, of the current flow and of the anodes when raised.

3.2 Identified KPIs for aluminium domain

3.2.1 Anode quality – business case 1

For the green anode production, two different process KPIs have been identified:

- green anode density variability;
- anode rejection rate.

The variability of the green anode density affects its behaviour on the pots and can lead to instability of the pot and to anodic incidents.

Anodes are being rejected if their density or their height are abnormal. Any rejected anode is reintroduced in the green anode production process. The anode blocks are crushed in a specific workshop to a required dimension before being reintroduced as green recycled product. Even if the impact of raw material is reduced thanks to the internal recycling process, this specific step is energy consuming and leads to inefficiencies along the production process.

For the project, focus is set on batches of anodes produced per 30 minutes periods. During iteration 1, a period was considered of lower quality if at least one anode produced had a density below 1620 kg/m^3. However, for iteration 2, a new definition of lower quality periods has been explored by data scientists, using the median density in the period, with a low-density threshold varying over time (e.g. based on last 6 months of production): the mean density of produced anodes is indeed varying over time mostly because of the variability of the raw material quality. The possibility to use thresholds specified by process experts for the overall KPI is under investigation at present stage of the project. This solution may help in dampening the effect of variations in some process variables (i.e. variability of raw materials quality).

For both iterations, the KPI to consider is the number of lower quality periods.

The variables measured in the paste plant which were found to be the most important for this KPI are the following:

Table 1 - List of considered variables for the anode density

Tag name	Variable[2]
D110-M120_DEPRESSION_FILTRE,	M120 filter (for condensers) underpressure
D110-J030_VIT_MOT_VIS_DEMANDEE,	J030 dosimeter screw requested velocity (medium silo)
D110-J020_VIT_MOT_VIS_DEMANDEE,	J020 dosimeter screw requested velocity (under coarse silo)
D110-J030_DEB_INSTANTANE_DOSEUR,	J030 dosimeter instant flow (medium silo)
D110-J010_VIT_MOT_VIS_DEMANDEE,	J010 dosimeter screw requested velocity (under very coarse silo)
D110-J173_DEB_EAU_REFROIDISSEMENT_J173,	J170 cooler water flow
D110-J050_DEB_INSTANTANE_DOSEUR,	J050 dosimeter instant flow (fines silo)
D110-J080_DEPRESSION_FILTRE,	J080 filter (magnetic separator) underpressure
D110-J010_DEB_INSTANTANE_DOSEUR,	J010 dosimeter instant flow (under very coarse silo)
D110-SL3_MES_NIVEAU_MOYEN_SILO,	coke mixture silo SL3 level
D110-J160_INT_MINI_MALAXEUR,	J160 Buss mixer minimum intensity
D110-J170_NIVEAU_MELANGEUR_REFROIDIS,	J170 cooler paste level
D110-J172_INT_MOT_TOURBILLON,	J170 cooler tool motor intensity
D110-J160_INT_MOY_MALAXEUR,	J160 Buss mixer mean intensity
D110-K070_VIT_VIBRATION,	K070 control group for vibrocompactor K050_vibrating velocity
D110-J050_VIT_MOT_VIS_DEMANDEE,	J050 dosimeter screw requested velocity (fine silo)
D110-K060_VIT_VIBRATION,	K060 control group for vibrocompactor K040_vibrating velocity
D110-J160_MES_CORRIGE_TENDANCE_BOUR,	J160 Buss mixer intensity for the indication of jamming
D110-J160_VIT_VIS_MALAXEUR,	J160 Buss mixer screw velocity
D110-J160_INT_MAXI_MALAXEUR.	J160 Buss mixer maximum intensity

[2] The code *J[number]* before the variable name identifies the part of the production chain where the variable comes from

3.2.2 Electrolysis – business case 2

In the reduction area the main objective is to stabilize the pots. The KPIs are chosen along with process experts in order to be sure that they proper represent the stability of the pots.

For the second iteration and the entire electrolysis scenarios the following KPIs have been chosen:

- **Bath Height**: difference between the predicted height and the measured height
- **Thermal balance**: percentage of 'hot' pots, thus meaning percentage of pots over 970 °C

The bath height is used to monitor the model, in order to be sure that the predicted result reflects the measure. This KPI will be calculated every 32 hours for each pot with a deep historic of one month. In order to have a clear KPI it will also be calculated for all pots within the last month results. The associated statistics are the average and the standard deviation. This KPI will allow the process teams to see if the model is robust and if the predictions are trustable.

The idea is not to point out the lack of relevance of the model. In fact, it's the opposite: to prove to the process team that they can trust the prediction, and in the future maybe the bath height measure will be no longer needed. This can represent a major step for Aluminium Dunkerque plant. Indeed, the operational teams, and especially the operators, spend a relevant amount of time to measure the bath height, metal height and temperature of each pot. These measures represent one quarter of their time. If the prediction is correct and if the process team has not to manually take the measures anymore, it will be a major improvement for the plant.

The second KPI (thermal balance) aims at detecting pots exceeding upper temperature threshold. This KPI will be calculated every week. Indeed, when the temperature is raising above 970 °C there are many issues, listed in the previous paragraph. The most critical one occurs when the pot is drilled. Indeed, due to high temperature, the crust (solid bath covering the shell) can go back to liquid phase, exposing it to the corrosive bath. Unfortunately, the shell is not made to resist to this corrosion and is likely to break down. The pot is then stopped and needs to be refurbished. Such operations take around one week and significant amounts of time and money are consumed. The cost of such an incident is rather high, around one million euro, and must be avoided. Knowing when a pot temperature is going too high allows the process teams and operators to set up countermeasures to avoid the stop of the pot. Thanks to the predictive function the operational teams will be able to lower the KPI and make the whole pot line more stable.

4 Plastic domain

4.1 Identified business cases

In the plastic domain, injection moulding process has been considered to implement the concept of MONSOON.

The injection moulding production technology has emerged as the main vehicle to produce highly complex, precise, value-added commercial parts with tight tolerance and surface finish. Almost 90% of the total high-tech polymer materials production is processed by injection moulding. The actual market is very demanding, and the production of plastic pieces is changing from a low-quality mass production to high quality injection processes, where the pieces obtained must comply with rigorous quality tests. The characteristics of a certain piece do not depend only on the raw material, but also on the transformation process. Therefore, it is convenient to carry out an exhaustive control of the injection process, controlling all the parameters contributing to this process. The process of plastic injection is based on melting a plastic material and making it flow inside a mould, where a cavity is filled up, obtaining various forms that allow to manufacture a wide variety of products. In the following figure, there is a schema of an injection machine, where the three main parts of these machines are specified.

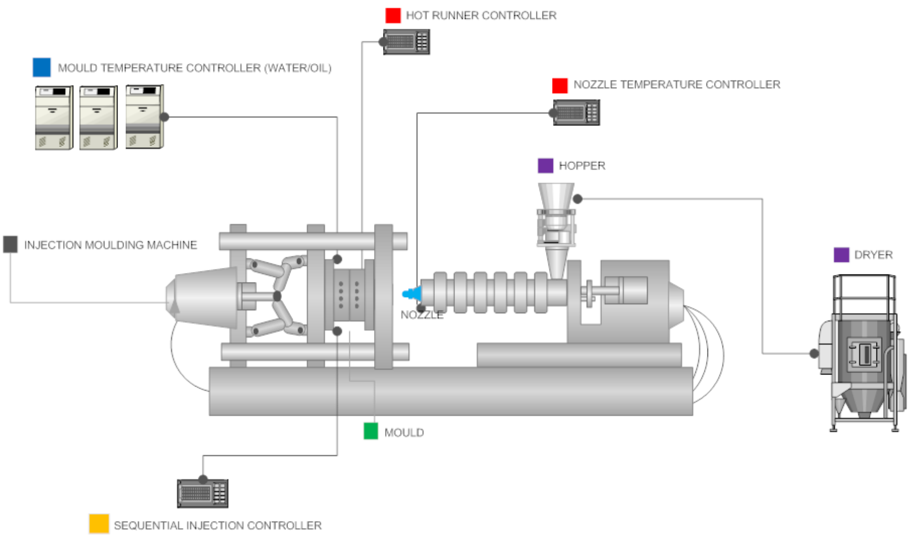

Figure 7 - Schematic view of an injection moulding production cell and related equipment layout

For the MONSOON project two different business cases have been selected:

1. **Coffee capsules:** a very high productive case with a low part complexity;

2. **Automotive parts:** a very technical part, with intricate details but a low productive cadence.

It is expected that the MONSOON approach will lead to several enhancements related to:

- **Resource consumption:** a reduction in resource consumption can be achieved by reducing the number of scraps and maximizing their recycling in the same production process; however, this can be only possible if the recycled material kept the required proprieties for the purpose of the plastic parts. Since the two selected business cases are related to packaging and food industry and automotive safety security, the option of using recycled material is not possible.

- **Products quality:** the combination of several factors affects product quality. Most significant parameters to be adjusted are the geometry of materials, the lubrication required, the injection temperature, the mould temperature, the injection pressure, the number of injection cycles and the compulsory dimensional tolerances; their optimization is expected to lead to more efficient production;

- **Decrease of the non-OK parts:** this can be achieved by acting on maintenance and moulding parameters setup. Today, the process is manually repeated until the machine starts to produce parts at desired quality level, producing an indefinite number of poor-quality products or even waste. This process could be sensibly optimized through a predictive model, allowing the production management to evaluate the optimal parameters for a more efficient injection process and waste decrease;

- **Mould process problems solving:** if a non-quality product is spotted, the corresponding machine/mould must be stopped until the problem is solved. The problem can be the consequence of a severe issue (e.g. mould damaged or broken); the proper repair or substitution might take up to three weeks. Thanks to the MONSOON approach, a specific problem can be recognized by large scale data analysis, reducing the number of wasted parts produced; the repair operations can be immediately triggered as well.

The impacts for the European plastic industries exploiting the MONSOON innovation might be rather relevant, such as:

- **Overall financial value at stake, and industry sustainability:** based on three main types of predictive functions: predictive maintenance (Asset Health Management), process optimization (on all injection processes: power, fusion, compression, injection) and predictive quality (on the injection parameters definition: temperature, injection speed, and temperature), the MONSOON project will allow the Production Management Teams to implement through large scale data collecting and real-time analysis, the algorithms which will maximize the company value;

- **Social Impacts:** under the current European conjecture, the plastic represents almost a nowadays dependence and the growth of the plastics industry affects several sectors of the European economy. The plastics industry is a key to the innovation of many products and technologies in other sectors like healthcare, energy generation, aerospace, etc. In other hand the plastics can assume a leading role as a strong contributor to a more sustainable and resource efficient Europe.

4.2 Identified KPIs for plastic domain

4.2.1 Coffee capsules – business case 1

In the first iteration focus was set on the business case 1, analysing all the consumption factors associated, namely the raw material consumption, parts quality control (OK vs NOK parts) and the corresponding waste that is generated as well as the energy consumption.

Despite the business case 1 has a 2% rejection rate for the produced parts, there is still room for improvement: less process stoppages, less mould faults/errors, decrease of the energy consumption based on optimized injection setups and less waste production. It must be noticed that, for a high-volume product (such as coffee capsules), even a very low rejection may lead to a significant yearly amount of waste; therefore, small reduction of this parameter might have a positive impact on the overall process sustainability.

KPIs for this business case are then defined as follows:

- **Rejection rate**: number of bad quality parts for each shift[3]

[3] This KPI, as well as the resource consumption, should be evaluated in steady-state production; during tests and setup phases, its value is expected to be out the confidence range due to the abnormal machine operating conditions

- **Resource consumption**: amount of material and energy resource consumed per each shift.

4.2.2 Automotive parts – business case 2

For the second iteration the goal is to fine tune the framework developed for business case 1 and present a framework for business case 2. In fact, the business case 2 should be very similar to first one, but with some add-on KPIs: it is a lower cadence production scenario, supplied by an additional variable set – sensors *in-mould*.

Business case 2 is centred in a plastic part for automotive vehicles that performs the role of a security connector responsible for turning off the vehicle in case of an accident. Because of this function, it is considered as a critical part and so it must follow rigorous specifications and tolerances. The specification sheets demand that the part presents the defined dimensions and composition – this reflects a major concern around the quality of the final plastic part.

To ensure the quality of the plastic part, there are two main vectors that needs be the controlled:

a) The mould tool should behave correctly and produce without faults and gaps – this relates to the mould maintenance.

b) The injection process should be adjusted to maximize the quantity of good parts – this correlates the injection parameters with the temperature and pressure sensors data, to visualize the behaviour of the mould during the injection process and identify which parameter should be balanced for a better-quality result, which is directly affecting overall injection process efficiency.

The production of automotive parts is a sub-product that feeds the automotive industrial line (in the client); because of this factor, a certain quantity of plastic part needs to supply every week, to avoid stoppages in the production line – this is correlated to machine stoppages, mould breakdowns and bad quality parts.

Beside the KPIs already defined for business case 1, business case 2 will additionally focus on the machine stoppages and labour time. Also, the data coming from the in-mould sensors could contribute as an indicator of quality for efficiency of the injection process.

The conjugation of these additional KPIs with the consumptions (raw materials and energy), will give a more complete scenario of production overview and reflect the behaviour of the production line concerning the impacts on the environment.

Defined KPIs for business case 2 are the same as business case 1, as they are related to quality control of the manufactured parts. Additional indicators arising from the adoption of new equipment in the moulding machines are out of the scope of this deliverable, as they will not be part of the MONSOON framework implemented within project lifetime.

Chapter 6 provides details about how the process-specific KPIs described in chapters 2 and 3 are merged with cross-sectorial KPIs into the evaluation framework.

5 Replicability

This chapter presents considerations related to the scalability potential of the MONSOON platform in other domains. During the 3 years of the project, a significant effort led to the design, development, testing and validation of algorithms, components and functions to optimize process industries described above. As the process industries cover a wide range of different manufacturing lines, machines, processes and operations, replication of the MONSOON platform should be as easy as possible to ensure a proper market breakthrough. As no specific KPIs can be defined to evaluate the easiness of deployment of a complex architecture such as the MONSOON one, this section contains guidelines about how the platform is built and how the components are designed from the infrastructural point of view.

As detailed description of the component from ICT point of view is out of the scope of this deliverable, please refer to [RD.1] and, for more general description of MONSOON, to deliverables issued by WP3 and WP4.

In the next paragraphs first an overview of the Runtime Container is presented; specific information is then provided to better understand how the MONSOON infrastructure works.

5.1 Using Docker to create a reproducible platform

The technical solution for the Runtime Container is based on containerization. A micro-services architecture does not dictate the use of containers, but most organizations that move to micro-services architectures will find containers a more congenial way to implement their applications.

5.1.1 Containers overview

Containers are an abstraction at the app layer that packages code and dependencies together. Multiple containers can run on the same machine and share the OS kernel with other containers, each running as isolated processes in user space. Containers take up less space than VMs (container images are typically tens of MBs in size), can handle more applications and require fewer VMs and Operating systems.

5.1.2 Docker

Docker Community Edition[4], used in the MONSOON project, is an open source software that provides the capability to package an application with its runtime dependencies into an image, and automates the deployment of Linux or Windows Containers based on such images. Figure 8 reports an overview of how Docker works and relations between apps and host:

[4] Even though Docker description is out of the scope of this deliverable, as several MONSOON documents deal with it, further information can be found at www.docker.com

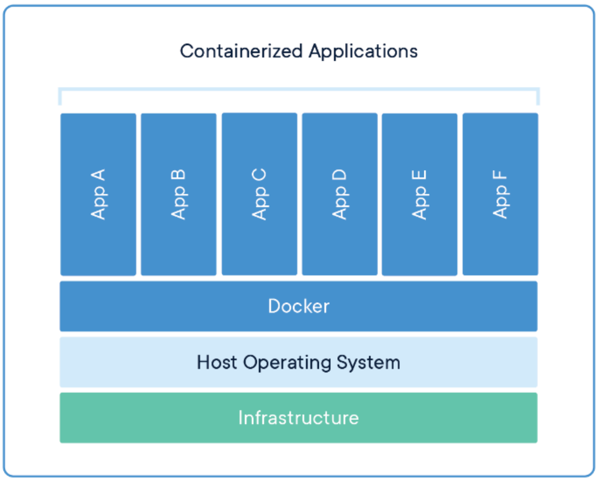

Figure 8: Docker operating scheme

5.1.3 Benefits of using Docker and Containers

Using Docker containers benefits both developers and system administrators with advantages such as:

- *Rapid application deployment* – containers include the minimal runtime requirements of the application, reducing their size and allowing them to be deployed quickly.
- *Portability across machines* – Docker containers can be deployed without regard to the Operating System on the host machine. Still, a container built on a machine with specific hardware architecture needs to be deployed on the same hardware architecture. In the MONSOON project only x64 architecture are supported.
- *Version control and component reuse* – successive versions of an image can be tracked, roll-backed to previous versions and differences inspected. Images reuse components from the preceding layers, which makes them noticeably lightweight.
- *Sharing* – a remote repository can be used to share images with others. Docker, Google, Red Hat provides registries for this purpose, and it is also possible to configure an own private repository using Apache 2 licensed Docker Registry.
- *Simplified maintenance* – Docker reduces effort and risk of problems with application dependencies.

5.1.4 Benefits using Docker-compose

Compose is a tool for defining and running multi-container Docker applications.

With Compose, a YAML file (YAML stands for Yet Another Markup Language) must be used to configure one application's services. Then, with a single command, it is possible to create and start all the services using the configuration file. Compose leverages Docker in order to manage the whole lifecycle of applications. Its most common features are:

- Start, stop, and rebuild services
- View the status of running services

- Stream the log output of running services
- Run a one-off command on a service

Docker and containers alone allow applications to be deployed without regard to the underlying Operating System, but there is still a need to orchestrate those containers and make them interact with each other.

Compose is a suitable tool for managing Container based applications lifecycle and allows to strive for a better reproducibility in MONSOON project. Deploying the MONSOON platform should involve updating Compose configuration files but should never involve modifying or building application images.

5.2 Using Ansible to deploy a reproducible environment

In order to deploy the MONSOON platform in a robust way and ensure that any environment can be reproduced, Ansible, a task automation framework, is used to prepare the target infrastructure and actually deploy the components.

5.2.1 Ansible Overview

Ansible is an open-source tool for software provisioning, configuration management and application deployment. It can be installed on many Unix-like systems and can configure both Unix-like systems as well as Microsoft Windows systems.

It uses no agents - temporarily connecting remotely via SSH or remote PowerShell to do its tasks - and no additional custom security infrastructure. Most importantly, it also handles YAML language, in the form of Ansible Playbooks that allow the user to describe automation jobs in a way that approaches plain English.

Ansible works against multiple systems in one infrastructure at the same time. This is done by selecting portions of systems listed in Ansible's inventory. It is possible to specify an inventory file using the command line.

Not only is this inventory configurable, but it is also possible to use multiple inventory files at the same time and pull inventory from dynamic or cloud sources or different formats (YAML, ini, etc). Introduced in version 2.4, Ansible has inventory plugins to make this flexible and customizable.

Below an example of Ansible Playbook is reported:

```yaml
---
- hosts: webservers
  become: true
  become_user: root
  tasks:
  - name: ensure Apache httpd is at the latest version
    yum:
      name: httpd
      state: latest
  - name: write the apache config file
    template:
      src: templates/httpd.conf.j2
      dest: /etc/httpd.conf

- hosts: databases
  become: true
  become_user: root: root
  tasks:
  - name: enable selinux
    command: /sbin/setenforce 1
  - name: ensure postgresql is at the latest version
    yum:
      name: postgresql
      state: latest
  - name: ensure that postgresql is started
    service:
      name: postgresql
      state: started
```

This playbook is not used in MONSOON project but illustrates how Ansible enable administrators and operation teams to manage infrastructure with ease. In this case, two groups of machines are targeted. The first list of tasks is executed on web servers, whether the second one is executed on databases. It is up to the inventory to specify which host belongs to which group.

5.2.2 Automating Infrastructure

Setting up the nodes on which the MONSOON platform will be installed can be done quickly using Ansible Playbooks. The following playbooks are available and require little configuration to adopt to one's needs:

- ***setup_users.yml***: Create users and define SSH policy on each target node.
- ***setup_packages.yml***: Upgrade distribution to latest available version and install system dependencies on each target node.
- ***setup_firewall.yml***: Install firewall if needed, configure network policy. Allow each node of cluster to communicate with fellow nodes.
- ***setup_docker.yml***: Install Docker Community Edition on each target node.
- ***setup_swarm.yml***: (Optional) Install Docker Swarm in a cluster of machines, instantiate Swarm cluster on a Master node and let pending node join the new cluster.
- ***setup_load_balancer.yml***: (Optional) Install an HA proxy instance that redirect traffic to Swarm cluster Ingress network.

Each of those playbooks execution can be configured by modifying configuration files associated with the target environment.

Moreover, each of those playbooks can be executed on:

- RHEL 7
- CentOS 7
- Ubuntu 16.04
- Ubuntu 18.04
- Debian 9

5.2.3 Automating MONSOON deployment

A single playbook is available to deploy the MONSOON platform. It can be used to both prepare Docker infrastructure (networks and secrets) and deploy Docker containers using Compose files. Thus, in order to deploy the MONSOON Data Lab for example, it is only needed to update configuration of each Compose file.

5.2.4 Benefits of using Ansible

- ***Declarative instead of procedural*:** The desired state of the entire IT infrastructure can be described in the form of Ansible Playbooks, which are files written in a very simple language, YAML.
- ***No Agent:*** As long as the target node has Python installed and can be reached using Python, it can be configurable using Ansible.
- ***Idempotent:*** When executing a Playbook, Ansible first checks if the states defined by the playbooks is different from the current state of the nodes. Only if a configuration change is required, does it execute the playbooks. If a playbook is executed multiple times, it's ensured that the nodes are configured the same every time without any side effect.

- ***Version control:*** Deployment scenarios can be described as Ansible Playbooks and stored in Version Control Systems. Successive deployments can be tracked, and roll-backed to previous version if needed.
- ***Component reuse:*** Ansible allows users to create "roles" which are a collection of tasks. Those roles can be imported directly from playbooks and shared amongst any playbooks.

5.3 Limits of reproducibility

Although most of MONSOON platforms component can be reused without modification in almost any kind of deployment, this is not the case for Data Flow Management Processors.

Those processors are part of the VPIRA and are responsible for collecting and standardizing domain-specific data. It might be needed to develop new ones in order to retrieve data from a new software or machines using a different protocol. Each processor is designed for a specific data source, and thus, is hard to reuse in a different context.

5.4 Conclusions and considerations

Both Docker and Ansible bring a positive contribution to the reproducibility of the MONSOON project.

The first allows application to be packaged with their dependencies into small images that can easily be transported, then deployed as containers in isolated environments.

The second allows infrastructure to be managed with simple configuration files and tracked over time in a Versioning Control System. A whole fleet of machine can be configured in a matter of minutes and any MONSOON environment can be reproduced quickly.

It can be said that the MONSOON infrastructure is designed to be easily deployed and replicated in other environment for infrastructural components, which are responsible for the overall proper functioning of the system. Concerning primary data retrieval, as each domain will have its own machines and lines with their own configuration in terms of network and monitoring systems, it can be assumed that new connectors must be deployed from scratch. Same consideration applies for visualization tools, as different industries may have different requirements in terms of dashboard features and design.

Table 2 gives an overview about how replicable and scalable MONSOON is according to the classification provided in this deliverable:

Table 2 – Qualitative replicability of MONSOON

Component	Goal of the component	Replicability	Comment
Runtime Container	To orchestrate deployment, test and run of predictive function in the industrial domain	easy	The whole component is designed and realized based on Docker
Connector/VPIRA	To retrieve primary data from site and transfer them into MONSOON environment	hard	Each machine or data acquisition system has its own communication protocol and other features which make this component very hard to reuse
Predictive function	To manipulate primary data to give an output which leads to process optimization	medium	Replicability of predictive functions is highly dependent on the way the function is written. Even if the function is written in a general manner, its scalability might depend on the goal (e.g. a maximization function is likely to be easier to scale in another domain than a function to control liquid aluminium temperature)
LCA plugin	To provide environmental KPIs populating the Evaluation Framework	medium	The LCA plugin converts primary data into environmental indicators for sustainability purposes. While the methodology is quite easy to deploy in several domains, the actual implementation of the component may require an update of background algorithms and databases

Please note this matrix is a qualitative estimation of the degree of scalability of MONSOON to other industrial domains. This qualitative analysis reveals that the infrastructure of the platform is quite easy to replicate in other domains, while specific components such as connectors cannot be reused unless in case of unlikely similarities; computational components such as LCA plugin and predictive functions can be deployed in another domains with moderate effort, exploiting large amount of existing infrastructure and updating background algorithms only.

In Table 3 a list of potential indicators to estimate the easiness of replicability of the MONSOON platform from software/infrastructure point of view is presented:

Table 3 – Example of replicability parameters

Indicator	Unit	Meaning
Number of configuration changes	amount	Number of changes in configuration setup required to adapt MONSOON to another domain different to the pilot ones. A change is defined as every kind of modification in whatever infrastructural component
Estimated Effort for update	low-medium-high	An estimation of the effort required to update a connector to retrieve different data from different machines or data acquisition systems
Infrastructure adaptation	amount	Amount of new components which need to be developed to ensure the proper operation of MONSOON from infrastructural point of view

6 Evaluation framework structure

In this chapter, the use case knowledge, which has been detailed in Sections 3 and 4, is used to populate the evaluation matrix for the MONSOON project. Each indicator (KPI) is characterized by name, class, measure unit, source and a description of the rationale behind it. It must be noticed that detailed description of the mathematics behind the computation of each indicator is out of the scope of this deliverable, for several documents have been issued by the MONSOON consortium regarding this topic. In addition to the previous consideration, the goal of this deliverable is to describe the rationale behind the chosen KPIs. Additional information can be retrieved from the documents reported in Chapter 2.

The evaluation framework is divided in two different blocks: a common layer where cross-sectorial KPIs are reported, and a domain-specific layer, where indicators that are relevant just for some use cases are stored. The combination of these two layers provides the final version of the evaluation framework for the MONSOON project close to the end of iteration 2.

An additional disclaimer needs to be mentioned about Environmental KPIs: these indicators are computed referring to a *Cradle to Gate* perspective; this means that they account for impacts generated directly by the process (such as the combustion of fuels or the emissions to air) and impacts generated in the upstream (such as the mining of materials). Whenever this perspective is not adopted for an Environmental KPI ("Process yield" indicator), it is mentioned in the description of the indicator; otherwise, it shall be assumed that the *Cradle to Gate* perspective is adopted.

6.1 Base layer

Table 4 - Evaluation framework: base layer

KPI name	Unit	Origin	Class	Description
Global Warming	kg CO_2 equivalent	LC management plugin	Environmental	Total amount of equivalent greenhouse gases generated by the investigated process
Primary Energy Consumption	MJ equivalent	LC management plugin	Environmental	Total amount of primary energy required to manufacture the investigated product
Direct Energy Consumption	MJ equivalent	LC management plugin	Environmental	Total amount of energy (electric and thermal) directly consumed by the investigated process
Electricity consumption	MJ	LC management plugin	Environmental	Total amount of electricity directly consumed by the investigated process
Raw material consumption	kg	LC management plugin	Environmental	Total amount of material required to manufacture a unit of valuable product
Recycled content	%	LC management plugin	Environmental - process	Percentage of recycled material in the investigated product
Water Consumption	l	LC management plugin	Environmental	Total amount of water required to manufacture the investigated product
Waste to landfill	kg	LC management plugin	Environmental	Total amount of waste originated from the process which manufactures the investigated product and sent to landfill
Waste to recycling	kg	LC management plugin	Environmental	Total amount of waste originated from the process which manufactures the investigated product and sent to recycling
Process yield	%	LC management plugin	Process	Ratio between the valuable output of the investigated process and the total input material

The base layer is mainly composed of Environmental KPIs: this is a reasonable configuration, for the Environmental class shows high cross-sectoriality. The selected indicators have been chosen according to a reliability criterion, which favoured KPIs with high robustness concerning the impact assessment method and the characterization factors to be adopted. All the Environmental KPIs are computed by the Life Cycle Management plugin implemented within WP5 activities; further information concerning this component is available in [RD.2].

The only process KPI included in the base layer is the process yield. This is because each process is expected to experience an increase of its yield due to the adoption of optimization techniques. Process yield is computed as a by-product of the LC plugin, as the evaluation of the yield is a required step in the process to compute Environmental KPIs.

During iteration 1, a Product Circularity Index (PCI) was introduced as an additional indicator. This KPI was devoted to quantifying the circularity of a product by means of a dedicated metric based on circular economy theories. Product circularity benefits from recycled material input in the production phase and from improved recyclability at the end of life; as the former contribution cannot be improved within MONSOON boundaries[5] and the latter is not handled by target MONSOON industries, it has been decided to exclude the PCI from the final Evaluation Framework.

The investigation of circular economy metrics represents a promising addendum to the platform in future developments. For intrinsic characteristics of the investigated processes, large use of secondary data for estimation of end of life scenarios is foreseen; this might deviate the original focus of the project, which is to use as many primary data as possible to build up reliable support for decision making and monitoring. The inclusion of a circularity KPI in the MONSOON platform represents therefore a powerful improvement but care must be taken while implementing such a KPI together with process-based indicators.

6.2 Domain layer: aluminium

For the domain layer, in the aluminium domain an additional column is added to describe whether the KPI refers to business case 1 (anode quality) or 2 (electrolysis).

Table 5 – Evaluation framework: domain layer (aluminium)

KPI name	Unit	Origin	Class	Business case	Description
Anode quality	number of low-quality batches	Dedicated predictive function	Process	Anode quality	Anode quality is evaluated referring to anode density; according to the computed density value, a batch of anodes is annotated as *good* or *bad*
Anode rejection rate	%	Dedicated predictive function	Process	Anode quality	Rejected anodes need to be recycled, with extra consumption of energy and machinery due to the crushing and re-forming processes

[5] Anodes can have a certain percentage of recycled content from the regrinding of bad-quality anodes. Once the anode is inserted in the electrolysis pot, it consumes the carbon fraction, so spent anodes cannot be fully recycled. The recycling of green anodes is a consequence of high number of bad parts, an effect which MONSOON aims at reducing at most (optimization of anode production means exactly that no bad anodes are produced)

Acidification Potential[6]	kg SO_2 equivalent	LC management plugin	Environmental	Anode quality	Potential of acidification and creation of acid rainfall arising from the production of the green anode
Natural gas consumption[7]	MJ	LC management plugin	Environmental	Anode quality	Total amount of natural gas directly consumed by the investigated process
Bath Height	m	Dedicated predictive function	Process	Electrolysis	Difference between the predicted height and the measured height
Thermal balance	%	Dedicated predictive function	Process	Electrolysis	Percentage of 'hot' pots, thus meaning percentage of pots over 970 °C

6.3 Domain layer: plastic

For plastic domain, a unique matrix is identified as the domain-specific KPIs are the same for both business cases.

Table 6 - Evaluation framework: domain layer (plastic)

KPI name	Unit	Origin	Class	Description
Rejection rate	%	Dedicated predictive function	Process	Percentage of waste capsules produced
Resource consumption[8]	kg/kg	Dedicated predictive function – LC plugin	Process	Amount of material required to produce 1 kg of part during one shift (the closer to 1 the better)

[6] At present stage (M30) this KPI is not computed for Electrolysis. The LC plugin in its final version will be designed to compute this indicator if the user requires it
[7] Same as above
[8] During final LC plugin development, this KPI will be discussed and validated with GLN team. The unit and the reference flow may change but the rationale of the indicator is likely to be maintained.

7 Conclusions and developments

This deliverable refines the set of specifications for the Evaluation Framework (EF) of the MONSOON project. After a description of the rationale behind the evaluation matrix, a description of the use cases investigated during iteration 1 and 2 has been reported; the structure of the Evaluation Framework has been depicted in Chapter 6, and an example of its application is presented in the ANNEX.

The most relevant outcome from the Final Evaluation Framework is the set of KPIs to be used to monitor the effectiveness of MONSOON application to the industrial domains involved. The KPIs have been clustered in different classes, which combination allows to achieve a holistic perspective covering either process, environmental and usability aspects.

Environmental and process KPIs are described with the same logic depicted in the initial EF; they are updated and adapted to different business cases according to MONSOON progress. The description of how the MONSOON platform is built from the infrastructural point of view gives a glance of how to deploy and decline the overall system in a different domain. This can be considered as the major update from initial to final EF version, and may provide insights about how to effectively exploit the developed platform.

Two major steps are foreseen towards the final implementation of the Evaluation Framework in the MONSOON package. The first action is the integration of the KPI matrix into the MONSOON platform as an online component. At this stage, the Evaluation Framework design has been coordinated by LCEN and other partners as a static component which is populated with results of offline and online calculations; an online integration of this component is likely to bring the project a higher level of robustness and would allow domain experts to actively monitor the effects of MONSOON.

The second action involves the graphical shape of the Evaluation Framework. At this stage, the component is in tabular form; an active representation based on dynamic dashboards might enhance the usability of the component and would allow to directly compare KPIs before and after the application of different MONSOON optimization techniques.

The next six months will be used by the MONSOON consortium to validate and refine the hypotheses presented in this deliverable. Discussion should address how to integrate the Evaluation Framework in the MONSOON platform; the business plan which has been developed during the last segment of the project may serve as a reference to understand where and how to integrate the Evaluation Framework to bring the project added value and enhance its potential in front of potential market users.

8 ANNEX: Example of environmental KPIs

This annex presents an example about how the evaluation matrix depicted in the previous sections is populated in the MONSOON platform. The reported indicators have been computed offline by LCEN and other data scientist partners using algorithms and techniques that will be replicated online in the dedicated components of the platform. Some specifications about these components are available in [RD.1], [RD.3] and [RD.4].

Goal of this section is not to provide ultimate and validated results, but to give a glance about how the Evaluation Framework could work at the end of iteration 2 of the project.

An additional disclaimer regards the flow to which the KPIs are referred to. This *reference flow* is reported for each indicator in each application of the Evaluation Framework. A representativeness criterion has been adopted for the selection of the reference flow: for aluminium domain, most of the KPIs are referred to a single anode, while for plastic most of the KPIs are referred to one kilogram of produced capsules. It must be noticed that direct comparison of KPIs coming from different domains is out of the scope of MONSOON, which main goal is to provide domain experts with a set of meaningful KPIs to enhance process performances.

8.1 Evaluation Framework: aluminium domain

In this section, an example of Evaluation Framework applied to aluminium domain is reported for iteration 1 of the MONSOON project.

As this is an explanatory representation which aim is not to provide extended results, a sample reference time has been chosen. In particular, reported KPIs are referred to the average green anode production from September 2016 to June 2017.

Table 7 - Evaluation Framework applied to aluminium domain, (average green anode production, from September 2016 to June 2017, Aluminium Pechiney facilities). Green lines represent the base layer, blue lines contain domain-specific KPIs.

KPI name	Reference flow	Unit	KPI value	Comments
Global Warming	Anode	kg CO_2 equivalent	566	-
Primary Energy Consumption	Anode	MJ equivalent	60 480	-
Direct Energy Consumption	Anode	MJ equivalent	565	-
Electricity consumption[9]	Anode	MJ	55	-
Raw material consumption	Anode	kg	1082	-
Recycled content	Anode	%	26,1	-
Water Consumption	Anode	l	5 400	-
Waste to landfill	Anode	kg	0,2	-
Waste to recycling	Anode	kg	0,3	-
Process yield	-	%	92	-
Anode quality	Batch	%	8,5	Percentage of 30 minutes periods with lower anode density
Anode rejection rate	Anode	%	N/A	This KPI has not be computed during iteration 1[10]
Acidification Potential	Anode	kg SO_2 equivalent	9	-
Natural gas consumption	Anode	MJ	510	-

[9] During iteration 1, only mixer electricity has been considered in the analysis
[10] Aluminium Dunkerque fixed the target value for this indicator at 2,5%; second iteration of the project will explore the opportunity to compute the KPI and to include it in the Final Evaluation Framework

8.2 Evaluation Framework: plastic domain

In this section, an example of Evaluation Framework applied to plastic domain is reported for iteration 1 of the MONSOON project.

As this is an explanatory representation which aim is not to provide extended results, a sample reference time has been chosen. In particular, reported KPIs are referred to coffee capsules produced during 2017 in GLN facilities.

Table 8 - Evaluation Framework applied to plastic domain, (coffee capsules production, year 2017, GLN facilities). Green lines represent the base layer, blue lines contain domain-specific KPIs.

KPI name	Reference flow	Unit	KPI value	Comments
Global Warming	kg of capsules	kg CO_2 equivalent	2,7	-
Primary Energy Consumption	kg of capsules	MJ equivalent	87	-
Direct Energy Consumption	kg of capsules	MJ equivalent	8	-
Electricity consumption	kg of capsules	MJ	8	-
Raw material consumption	kg of capsules	kg	1,26	-
Recycled content	kg of capsules	%	0	-
Water Consumption	kg of capsules	l	18	-
Waste to landfill	kg of capsules	kg	-	-
Waste to recycling	kg of capsules	kg	0,26	-
Process yield	injection process	%	79	-
Rejection rate	kg of capsules	%	3	-

9 ANNEX: Operating procedures and training material developed for the Dunkirk plant

This annex is intended to report some examples of the new operating procedures developed in the anode paste plant of the Dunkirk production site. For confidentiality issues, sensitive data are blurred; however, this is a representative example about the integration of the MONSOON concept in the very core part of the production.

First, a general example of component deployment is reported; the configuration pattern can be assumed as constant, while the visualized variables and plots may change according to the specific goal (e.g., whether the user is interested in visualizing environmental KPIs or predictive maintenance-related KPIs, etc.).

In the second section of this annex the configuration procedure of the LCA plugin is reported.

The workers and the process engineer of the paste plant at Aluminium Dunkerque have several operating procedures in order to drive the paste plant, on plant start-up, on equipment, safety and also quality control. There is a continuous improvement of all these procedures to the evolution of the equipment and process. Operating procedure change is a continuous process.

Predictive functions and LCA dashboards are new tools available for the process engineer. There is a change of operating procedure in the process engineer methodology, who learns how to work with MONSOON predictive function before transferring them to the work floor.

To ensure proper adaptation to the MONSOON platform, a training session was performed in Dunkirk on August 2019 by a joint team including members of CAP, Probayes, AP and LCEN. The whole material used for this training session contains several sensitive information from the Aluminium Dunkirk side, therefore it cannot be disclosed in this public deliverable.

Deployment of MONSOON components in the Dunkirk plant

Objectives of the MONSOON Platform in LAD

- **Implementation of MONSOON concepts:**
  - Realtime communication of data from existing systems (PI, MESAL, ALPSYS).
  - Persistent data storage.
  - Hosting and orchestration of predictive functions through their entire life cycle.
  - Predictive function results visualization through interactive dashboards.

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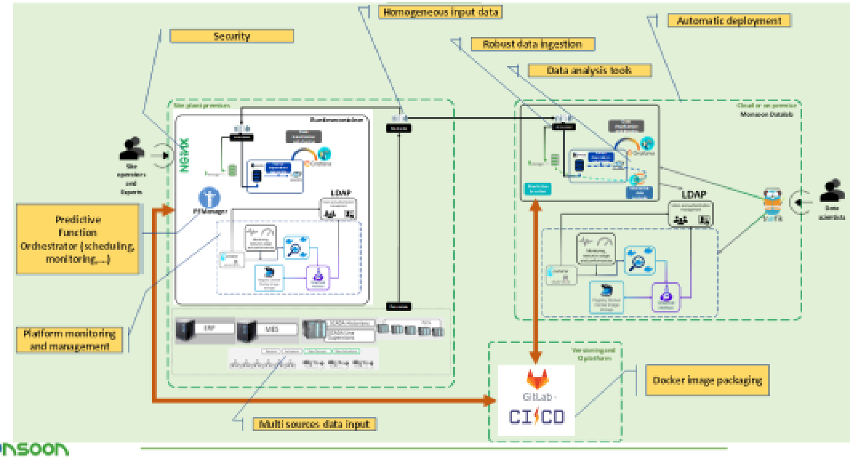
Technical Architecture Overview



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MONSOON Server Hardware Specifications

id:	monsoon.adk.local
description:	Rack Mount Chassis
product:	PowerEdge R440 (SKU=NotProvided;ModelName=PowerEdge R440)
vendor:	Dell Inc.
serial:	2S86JN2
width:	64 bits

id:	Red Hat Enterprise Linux Server release 7.4 (Maipo)

id:	cpu:0
description:	CPU
product:	Intel(R) Xeon(R) Gold 6130 CPU @ 2.10GHz
vendor:	Intel Corp.
vendor_id:	GenuineIntel
slot:	CPU1
size:	2100MHz
capacity:	4GHz
width:	64 bits
clock:	1010MHz
configuration:	cores = 16 enabledcores = 16 threads = 32

id:	memory
description:	System Memory
physical id:	1000
slot:	System board or motherboard
size:	64GiB

id:	disk
description:	SCSI Disk
product:	PERC H730P Adp
vendor:	DELL
physical id:	2.0.0
bus info:	scsi@0:2.0.0
logical name:	/dev/sda
version:	4.27
serial:	00ebb1df19ba3c4222007cec3e604609
size:	7450GiB (7999GB)

id:	network:0
description:	Ethernet interface
product:	NetXtreme BCM5720 Gigabit Ethernet PCIe
vendor:	Broadcom Limited
configuration:	autonegotiation = on broadcast = yes driver = tg3 driverversion = 3.137 duplex = full firmware = FFV20.6.52 bc 5720-v1.39 ip = 10.190.56.46 latency = 0 link = yes multicast = yes port = twisted pair speed = 1Gbit/s

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Accessing the MONSOON server from LAD network

- 1 user administrator
  - *Username*: <xxx>**
- This user can use *sudo* elevation to perform actions as *root* user.
  - *Example:* Checking the status of Docker daemon:
    - `sudo systemctl status -l docker`
- This user does not need elevation to execute commands againt the docker daemon
- Server can be reached using SSH (Secure Shell) using port <xx>** The private IPV4 address of the server in LAD network is « 10.X.X.X »**.
  - Example: Connection au serveur via SSH
    - `ssh <xxx>@10.X.X.X`

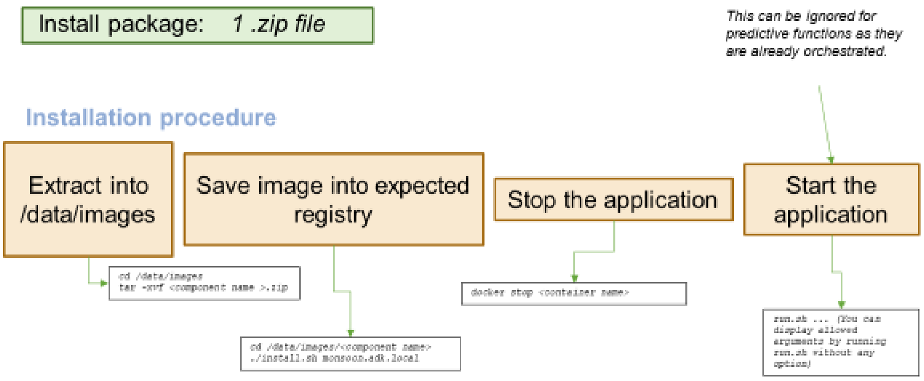
MONSOON August 2019 LAD Training ** Sensitive information has been removed from original slides

Components Deployment: Principles 4- Installation/upgrade

Delivery

Install package: *1 .zip file*

Installation procedure



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Identity Management

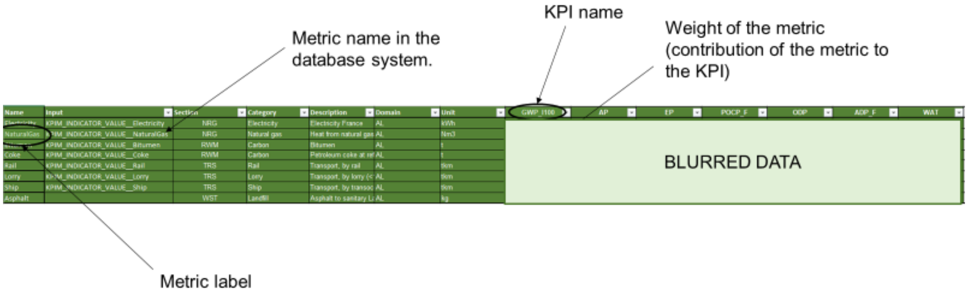
- An LDAP server (Lightweight Directory Access Protocol) is deployed within the runtime container.
- A super user has rights to create new users:
  - `DN: cn=<xxx>**, dc=monsoon, dc=eu`
- A user interface is accessible from https://<xxx>.monsoon.adk.local** and let administrators perform user management tasks easily.
- An other user interface is accessible from https://<xxx>.monsoon.adk.local** and let any user reset or update their password.

MONSOON August 2019 LAD Training ** Sensitive information has been removed from original slides

Configuration procedure for the LCA plugin

LCA Plugin Configuration

- **1 configurable Excel workbook:**
  - **1 sheet per sector (Carbon, Electrolysis)**



Note: A metric is an input for the plugin

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Computation example

- KPI: GWP_I100 (Global Warming Potential)
- Formula:

$$GWP\_I100_{shift} = (Electricity_{shift} * GWP_{electricity}) + (NaturalGas_{shift} * GWP_{gas}) + (Bitumen_{shift} * GWP_{bitumen}) + (Coke_{shift} * GWP_{coke}) + (Rail_{shift} * GWP_{rail}) + (Lorry_{shift} * GWP_{lorry}) + (Ship_{shift} * GWP_{ship})$$

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LCA Plugin orchestration

- The plugin is scheduled to run everyday at 2.30am, 10.30am and 18.30p.m.
- KPI values are computed over 8 hours periods, corresponding to the plant shifts (6h-14h, 14h-22h, 22h-6h)
- Results can be vizualized as soon as computation is over through the Grafana dashboards.

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Acronym

Acronym	Explanation
EF	Evaluation Framework
KPI	Key Performance Indicator
LC	Life Cycle
LCA	Life Cycle Assessment
ACD	Anode/Cathode distance
WP	Work Package
VM	Virtual Machine
OS	Operative System
VPIRA	Virtual Process Industries Resource Adapter
YAML	Yet Another Markup Language
PCI	Product Circularity Index

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