MAESTRI

Total Resource and Energy Efficiency
Management System for Process Industries

Deliverable **1.1**

# MAESTRI platform usage scenarios

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# 1. Executive Summary

The MAESTRI project aims to advance the sustainability of European manufacturing and process industries. This will be done by providing a management system in the form of a flexible and scalable platform and to guide and simplify the implementation of an innovative approach in organizations with the Total Efficiency Framework.

The overall aim of this framework is to encourage a culture of improvement within manufacturing and process industries by assisting the decision-making process, supporting the development of improvement strategies and helping to define the priorities to improve the company's environmental and economic performance.

Creating scenarios of end user behaviour and interaction with platform functionality is a very useful instrument for identifying key technological, security and business drivers for future end user requirements. The scenarios will provide the framework for subsequent iterative requirements engineering phases.

The purpose of this deliverable is to document and describe a set of plausible usage scenarios in 2020 and beyond for the MAESTRI Total Efficiency Framework in its three main areas: Efficiency Framework, Management System and Industrial Symbiosis.

The MAESTRI vision scenario in chapter 5 provides a holistic view on how the process industry in five to ten years could work and optimize their processes with the help of tools and methods created by MAESTRI in the three main areas mentioned above. The specific scenarios for the three MAESTRI main areas are more focused than the vision scenario and present various stakeholders working at the fictional company InnoProc.

The scenarios for the Efficiency Framework in chapter 6 mainly deal with assessing the current efficiency and eco-efficiency performance of the company by analysing monitoring data with respect to various KPIs. Such analysis supports the decision making process and enables "on the spot" decisions. It also helps to identify major inefficiencies and underpins sustainability. By using simulation an evaluation of the expected overall efficiency and eco-efficiency performance could take place that arises from technology replacement of an inefficient production system.

In chapter 7 the scenarios for the Management System show how lean tools and methods could be applied to support the vision of implementing and using continuous self improvement processes within the process industry.

Finally in chapter 8 various scenarios regarding industrial symbiosis describe not only how a company could identify waste but also monetize or reuse waste themselves. The scenarios cover situations dealing with different levels of government policies and legislation activities as well as data quality in waste production and management processes.



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## 2. Abbreviations and Acronyms

EIP - Eco-Industrial Parks

KEPI - Key Environmental Performance Indicators

KPI – Key Performance Indicator

IoT - Internet of Things

IS – Industrial Symbiosis

NISP – National Industrial Symbiosis Programme

ROI – Return on Investment



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# 3. Introduction

## Overview of the MAESTRI Project

The MAESTRI project aims to advance the sustainability of European manufacturing and process industries. This will be done by providing a management system in the form of a flexible and scalable platform and to guide and simplify the implementation of an innovative approach in organizations with the Total Efficiency Framework.

The overall aim of this framework is to encourage a culture of improvement within manufacturing and process industries by assisting the decision-making process, supporting the development of improvement strategies and helping to define the priorities to improve the company's environmental and economic performance.

Its development and validation will be achieved through application in four real industrial settings across a variety of activity sectors.

The Total Efficiency Framework will be based on four main pillars to overcome the current barriers and promote sustainable improvements:

a) efficiency assessment tools to define improvement and optimisation strategies and support decision-making processes;

b) an effective management system targeted at continuous process improvement;

c) a toolkit for Industrial Symbiosis focusing on material and energy exchange;

d) a software platform, based on the Internet of Things (IoT), to simplify the concept implementation and ensure an integrated control of improvement process.

Over a period of 4 years, the project will deliver exploitable results clustered into technological outputs (including eco-innovative products, processes and services tailored to industrial end-users) and structured solutions (involving technical, economical, legislative and policy solutions combined synergistically), following the already drafted exploitation activities, such as: Market analysis; Development of marketing strategy; Financial plan; Concept demonstration; and Implementation Plan.

## Purpose of this deliverable

The purpose of this deliverable is to document and describe a set of plausible usage scenarios in 2020 and beyond for the MAESTRI Total Efficiency Framework in its three main areas: Efficiency Framework, Management System and Industrial Symbiosis.



Creating scenarios of end user behaviour and interaction with platform functionality is a very useful instrument for identifying key technological, security and business drivers for future end user requirements. The scenarios will provide the framework for subsequent iterative requirements engineering phases.

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Based on the scenarios and storylines, a systematic formalisation of all relevant user requirements and subsystems requirements will be derived.

The basis will be user-centric requirements originating from the ecosystems of the MAESTRI industry partners. These include functional requirements, energy requirements and business requirements. The non-functional societal requirements will include requirements related to ethics, inclusion and data protection, quality of use, legal, etc.

The deliverable documents the work undertaken in task T1.1 Scenario Thinking and provides top-level user requirements in the form of a vision scenario of the future use of the MAESTRI platform as well as more detailed scenarios for each of the three main areas (Efficiency Framework, Management System and Industrial Symbiosis). The next step will be to produce the initial set of requirements based on user-centred workshops with representatives from the industry partners in MAESTRI. This work will be conducted in task T1.4 Initial Requirements Elicitation.



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# 4. Scenario Thinking

## Introduction

The vision scenario aims to provide a coherent, comprehensive, internally consistent description of plausible futures built on the imagined interaction of key trends for the process industry with respect to the three main areas (Efficiency Framework, Management System and Industrial Symbiosis).

Making reliable predictions about future user requirements calls for a great deal of certainty - an adequate level of knowledge and confidence in our assumptions about that knowledge. But defining user requirements today is extremely complex, as it is taking place in a fast-changing, information- and technology-driven environment. On their own, familiar planning and forecasting practices that have served us well in the past cannot deliver the insights and answers necessary in today's world of shifting values and policies, changing social structures and behaviour, which increasingly challenge predictions of how the future will look.

The process of Scenario Thinking (or Scenario Planning as it is sometimes called) is widely recognised as a tool for creating user requirements specifications under uncertainty.

Scenario Thinking is not about predicting the future; neither is it about choosing the best way forward, though it is indeed a powerful and invaluable tool to this end. Its primary value lies in the development of new skills for improving the definition and planning of user requirements.

Developing and deploying these skills enables us to transcend the specific or narrowly defined solution, to go beyond short-term or one-off successes and acquire a consistency and robustness in coherent long-term user scenarios. We come to know the right questions to ask and where to look for answers to open issues; how to recognise unique opportunities and choose the best way to go.

The first step in Scenario Thinking requires us to anchor ourselves securely in the present. When thinking about the future, we always do so within a context, and a starting place provides an opening array of ideas or facts, which in turn are related to some perception of a desired goal or objective for future user interaction.

As we convert this information into well-defined stories of possible future situations and our options for action in these, we unveil the inherent uncertainties that must be dealt with or overcome. An obvious fact often forgotten is that these uncertainties have been initiated by our original thinking, assumptions, omissions and commissions.

The quality and disposition of original input will strongly influence the flow of thought, handling of material and quality of output. To make the best use of scenarios, our intentions must be explicit and the issues or areas to test have to be clearly identified.

The purpose of Scenario Thinking is to challenge the preconceived notions we may have of the future, allowing us to revise or revisit our accustomed approach. The process is intended to open up the way one thinks about the future. Scenarios help to identify threats, recognise opportunities and make choices about strategically important issues. A scenario illuminates



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the possible, what might be. It prods one to do something slightly counterintuitive; to go beyond the known into the unknown, outside one´s area of expertise.

While reading the scenarios one should think about answers to such questions as:

- Is this even remotely possible?
- Would the world be a better place in this scenario?
- If one were a stakeholder in this scenario, what would we be doing differently?
- If one knew for sure that this scenario was to come true, what would we do now?

In essence, the Scenario Thinking process is designed to arrive at several parallel, co-existing hypotheses about the future. These variant hypotheses are given a concrete form, and stakeholders can visualise them because they are embedded in a story or a scenario. In turn this means that the same person can look at the scenario through different sets of glasses and see things from different perspectives.

### *Development of the scenarios*

The scenarios were developed in a two-step process – first the research partners drafted the overall vision scenario and the initial context scenarios from their knowledge of the main areas of MAESTRI. Those draft scenarios were then provided to the industry partners for validation and extension.

The industry partners also shared their visions and ideas for the future use of the MAESTRI platform and based on their input the scenarios were enhanced, thus providing the final input for the context scenarios in section 6 and onwards. These scenarios combined with the conclusions from the user workshops will provide the foundation for eliciting functional and non-functional requirements for D1.4 Initial Requirements Report.

With a time horizon of 2020 and beyond, one of the main areas of development will unquestionably be related to the improvement of the process industry on a continuous basis and increase eco-competitiveness by fostering sustainability in routine operations. One of the major drivers for the EU community is the increased efficiency of energy and material usage as well as waste reduction, e.g. as it is stated in "A resource-efficient Europe – flagship initiative under the Europe 2020 strategy"[1], saying: "Using resources more efficiently will help us achieve many of the EU's objectives".

The area of development identified for the MAESTRI project goes a step further than just monitoring and collecting resource consumption and production data. The project also aims to provide a platform able to provide process industry companies with tools to correctly assess and evaluate their process efficiency and identify ways to improve the efficiency and potentials for using industrial symbiosis.



Some of the main areas to be considered are the following:

- Assessment of production system efficiency and overall efficiency as well as resource and energy efficiency

[1] http://ec.europa.eu/resource-efficient-europe/

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- Identification and tracking of the most relevant KPIs and KEPIs and decision support for improvement measures
- Embed energy and resource efficiency in both longer term strategies and daily improvement routines
- Support continuous improvement of economical and sustainability issues
- Identify new uses for by-products and potential use of the wastes internally in the plant or externally with other partners or by monetizing them



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# 5. The overall MAESTRI Vision Scenario

Michael is plant manager for the company InnoProc from the process industry. The company established goals to continuously increase sustainability and resource efficiency. This was done by using tools from a total efficiency framework to assess the production system efficiency and eco-efficiency performance.

The Key Performance Indicators (KPIs) for the company were defined using a standardized environmental impact assessment report for the company industry sector as a benchmark. The KPIs cover economic, environmental and efficiency enhancements coming from a life cycle analysis in order to increase efficiency, sustainability and cost savings.

Michael regularly checks the performance of the plant and if counter-measures need to be taken. He fires up the plant management dashboard where he can check the KPIs, either their current values or aggregated over different periods of time like daily, weekly or monthly intervals.

The data collection is automated, so that the energy and resource consumption as well as other process related activities will be monitored in near-real-time. Since Michael needs to make strategic decisions he is usually not interested in the actual real-time values but needs aggregated reports to analyse the overall/sector/unit process efficiency/eco-efficiency in order to make informed decisions "on the spot".

The plant manager also has access to specialized reports in the system that were automatically created in the past because of specific problems that happened in the plant. The identified problem causes need to be monitored more closely periodically.

Michael spotted two areas with existing inefficiencies and now he is working on finding effective counter-measures. One of the areas is resource and energy efficiency, the other is waste reuse. Michael noticed unusually high energy consumption and waste production in one production process step in the morning shifts compared to the two other shifts later in the day.

Michael opens the relevant management dashboard to have a look at selected KPIs and eco indicators in order to identify potential problems. He looks at the detailed data and discusses them with key people of the related departments in order to figure out the causes and potential solutions. Finally new target values are defined. The new targets are ambitious and Michael discusses them with Simon, who is the responsible shift supervisor.

Michael explains the importance of the improvements so that Simon understands how the improvement of certain eco indicators will result in tangible benefits for the company. On the management dashboard Michael can now show a plan to Simon which organizational improvement actions should be performed.



Simon is now able to communicate the new targets and the necessary organizational improvements to the team. The team members also know how they can measure their continuous improvement themselves to make sure they are on the right track to reaching the new target values.

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Regarding the second inefficient area that was identified, Michael wants to reuse waste (especially CO2 and dirty water) produced in a certain production line in order to reduce environmental pollution and operational costs.

Together with Lisa, the production line manager, Michael systematically identifies and maps material, energy and water wastes and pinpoints the location and process steps where the waste occurs. Together they check exploitation opportunities internally and externally via a total management system to characterise the waste and to assess the different opportunities to create value out of that waste, including elimination (either by changing processes to avoid the waste or by waste disposal) or exploitation.

By using an environmental and cost based modelling system, Michael and Lisa are able to evaluate the implications for the company by either elimination or exploitation of the waste over various timescales. They also have a look at the 'waste partners' marketplace to identify companies that are technically able to exploit the opportunities identified.

They identify that the most valuable route is exploitation in the medium term, which requires some investment by the company, but results in creating new sources of value most appropriate for the identified wastes. In their case they had the options of either selling the waste to another company or by re-using the waste internally in their plant in other processes. They went for the latter option so that they invested in a machine that extracts a useful material out of the waste which then is fed into the production process in another sector of the plant. The estimated ROI of that investment is 5 years which is acceptable to the management.



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# 6. Efficiency Framework (EF) Context Scenarios

## Introduction

The company InnoProc implemented a new management paradigm supported by environmental and economic KPIs. Top level managers (from the administration board and first level directors) define clear and consistent KPIs that include sustainability aspects in the company strategy and objectives to fulfil the "company's sustainability strategic goals".

The company is also focused on the optimized use of energy and resources, which will enable cost-savings and improved efficiency. Therefore InnoProc has been assessing, in real time, the production system's efficiency and eco-efficiency performance, making use of all available data. Such analysis: **a)** supports the decision making process and enables "on the spot" decisions, **b)** helps to identify major inefficiencies; and **c)** underpins sustainability (environmental and economical sustainability related aspects). Moreover, InnoProc is currently evaluating, through simulation, the expected overall efficiency and eco-efficiency performance that arises from technology replacement of an inefficient production system.

All monitoring data regarding energy and resource consumption in the plant is stored in a central data repository, which gets the data from all relevant devices. In order to reduce the probability of mistakes, the data gathering is automated and there is no need to collect data manually. In this context it is evident that plant IT infrastructure and real time metering devices are key enabling technologies.

Nevertheless, the methods and tools used by InnoProc are fundamental elements to treat and process the available data, i.e. transforming and integrating data into information in order to support the decision making process and to identify rapidly major issues, as well as enable the publication/communication of sustainability performance and improvement measures of unit process/line/plant.

## EF Scenario 1

John, the sector manager, has been monitoring the efficiency and eco-efficiency of a production line using the Total Efficiency Platform. He noticed that the system's efficiency (energy and resource consumption) and eco-efficiency performance were low. John also noticed that the system under analysis is the largest contributor in terms of costs, due to high running costs and low resource efficiency.

Several improvement actions were implemented in order to maximize the efficiency and consequently to reduce costs and environmental impacts. The enhancements that arise from the implementation of the improvement actions were tracked and measured in terms of economic, environmental and efficiency performance. Despite the slight improvement the results do not meet the required targets defined by Tracy, the plant manager.

John and Tracy have a meeting to tackle this issue. They analyse the improvement actions and the effective improvements. They quickly realise that the efficiency and eco-efficiency performance is limited by the technology, i.e. the production line cannot be much more



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efficient than it is with the currently used technology. So, the managers see the need to replace the existing technology in order to achieve the targets - reduce costs and environmental impacts.

John knows that investments for technology replacement will not be approved unless he is able to prove to the financial department and directors that the payback period is short. Besides investment, the plant manager also has to assess and prove that the new technology is more efficient, has lower running costs and lower environmental impacts.

For that purpose John uses the Total Efficiency Platform to:

a) support his decision,
b) collect evidence of the need for investment and
c) provide proof that the targets will be achieved.

Tracy, as plant manager, uses the methods & tools that are based on suppositional models in order to:

a) Predict/identify consumption patterns and emission projections of the new technology;
b) Forecast energy and resources efficiency; and
c) Simulate the impact of different scenarios.

Such decision support models enable John to forecast the environmental and economic impact and the overall efficiency increase. For instance, it was possible to forecast the overall effect related to the use of a different technology, and to conclude that replacing the existing technology is a must and the payback period is acceptable after that specific analysis has been performed.

## *EF Scenario 2*

The board of directors, alongside with the plant managers from InnoProc Plants A and B, meet to define the company's new sustainability targets for the next quarter and the following year. Plant managers have 6 months to achieve the goals.

Due to regulatory and cost issues as well as InnoProc´s company strategy, the board focuses on energy (electricity, fuel and gas), water and material consumption in addition to $CO_2$ emissions. The board and plant managers define the sustainability targets, taking into account the efficiency and eco-efficiency performance of the last period.

Following this meeting, both plant managers (from InnoProc Plants A and B) meet and analyse the results of the Total Efficiency Platform. They notice that Plants A and B, despite using identical processes, have large differences in some sectors regarding efficiency and eco-efficiency performance.

Consequently, the first step is to identify for each sector which plant has better efficiency and eco-efficiency performance in that sector. After that, the plant managers simulate what their plant efficiency would be if they were to combine the best performance of each plant, i.e. consider the highest efficiency and eco-efficiency performance for each sector. Promptly they notice that they would be close to the target. Yet, both plants still have to



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improve material efficiency by a target percentage and optimize water and energy consumption.

The plant managers define a work plan, involving their shift and sector supervisors, in order to share experiences and knowledge ("best practices" already used in each plant) on how to enhance efficiency and eco-efficiency performance. The teams from Plants A and B also work together to define improvement actions in order to improve water, energy and material consumption.

During the following months the improvement actions are gradually implemented. The shift manager from each plant explains to the sector workers the importance of achieving the targets. Managers also redefine the Total Efficiency dashboard configuration in order to show relevant KPI evolution and deviations from the target values on the display available on the shop floor, so workers can keep track of improvements and needed effort.

The plant managers and shift supervisors also keep close attention to the online real time process monitoring, provided by the Total Efficiency Platform, in order to continually identify and diminish/eliminate major misuses/inefficiencies. They also keep track of the economic, environmental and efficiency enhancements that are arising from the implementation of improvement actions and the best practises shared between plants.

Plant managers create on a monthly basis a standard report to document the efficiency and eco-efficiency performance of the respective plant to the Board. Since the reports are less subjective and more quantitative, the Board can easily evaluate if the goals are on track. The board members can evaluate the performance evolution of the relevant KPI (energy, water, material consumption and $CO_2$ emissions) online by using the Total Efficiency Platform. After the six month period all goals set were achieved by both plants. Moreover, the publishable results can be easily compiled in the company's annual sustainability report. The board also decides to send a brief standard report to some of the clients and external stakeholders with the goal of sharing their vision on sustainability.



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# 7. Management System (MS) Context Scenarios

## Introduction

The ISO 14001 standard has been implemented in the company InnoProc for several years. At the beginning, significant environmental aspects were identified and measured. However, Megan as the *Heat Treatment* Department Manager was not aware of the current state of these indicators and was not interested in improving them. This was partially because Megan and her other colleagues from middle management were not feeling responsible for that. They just felt responsible for such indicators like *on time delivery* or *defect rate*. Moreover, they were convinced that the eco performance improvements are only reachable through big investments like buying new machines.

## MS Scenario 1

Megan monitors the processes on a management board on her computer, with selected key performance and eco indicators exposed on it. For every indicator there is a chart with current trend vs. target available. Targets are ambitious and require improvements to be achieved. Megan has collaborated with Paul (Production Manager) in defining indicators and improvement targets. He understands why they are so important for the company (by using the Hoshin Kanri method[2]). Paul made an analysis using the total efficiency platform and now knows how improvements in specific eco indicators (monitored on his management board) result in tangible benefits for the company. The management board provides not only measurements for selected indicators but also a plan for improvement actions to achieve ambitious targets based on the indicator measurements (including eco indicators). Thanks to Eco A3, another tool of the total efficiency platform based on the A3 problem solving method[3], they know how to achieve the targets related to eco performance implementing organizational improvements.

## MS Scenario 2

Thanks to a workshop on *low-cost eco performance improvements* and case studies shown during that workshop, the plant manager Andrew is convinced that improving eco performance is possible without big investments. He got to know tools that help to achieve organizational improvements resulting in decrease of energy, water and gas use as well as reduction of material scrap and emissions. During the workshop Andrew himself has gained practical experience, since he has been involved in hands-on training in applying these tools in the host company. The workshop has been hosted by the company InnoConsult and people from 7 different companies participated. During the workshop, Andrew got to know representatives from other companies with similar problems and improvement needs. They have exchanged contact information and will be visiting each other's factories in order to talking about experiences with the new eco-oriented improvement approach.



[2] http://www.leanproduction.com/hoshin-kanri.html
[3] http://www.reliableplant.com/Read/22984/a3-problem-solving-lean

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# 8. Industrial Symbiosis (IS) Context Scenarios

## Introduction

Industrial Symbiosis (IS) *"engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products"* (Chertow, 2000). The lack of clarity regarding the concrete meaning of "separate industries" has given rise to a debate on the scope of IS by several experts (Lombardi and Laybourn, 2012). The definition of IS has been extended in scope to consider those cases in which IS may occur within a single company or industry as well as cases involving multiple companies from different industries (Short et al., 2014). On this basis, the scenarios for the IS context presented herein are mainly reflecting the opportunities for a single company to engage in IS without addressing specifically whether these opportunities are realised by the company itself alone or in partnership with other companies.

The implementation of IS can be initiated in different ways. These are the most common arrangements (Chertow, 2000; Domenech and Davies, 2011; Paquin and Howard-Grenville, 2012; Behera et al., 2012):

- Self-organized IS considers spontaneous symbiotic exchanges between companies, without external intervention and normally connected to personal/social links between managers.
- Facilitated IS regards the cases in which a third party temporarily supports the companies that are willing to engage in IS. An example of this is the National Industrial Symbiosis Programme (NISP) carried out in the UK, which provides facilitation to bring together relevant companies to develop IS exchanges and to replicate successful high-value exchanges.
- Planned IS refers to IS as a design approach for national programmes that fosters the implementation of Eco-Industrial Parks (EIP). In this type of projects the leadership remains in a third party, normally a national agency, which provides pilot studies and conceptual ideas as well as reviews EIP performance and revises the overall strategy if needed.

The following scenarios from an IS perspective are described according to potential extreme situations derived by two variables. The first variable is the *level of government support and intervention*. Government policies and legislation favouring IS are seen as one of the key enablers/barriers for its successful implementation (Sakr et al., 2011), thus, whether there is a strong legislative environment or not will definitely affect IS opportunities in manufacturing industries. The second variable regards the *quality of waste data*. It would be enhanced by the development of measurement technologies and of integrated standards related to waste characteristics. Standards and technologies have been pointed out as a key enabler for IS implementation (Grant et al., 2010). Therefore, whether they are improved or not in the upcoming years will definitely influence IS implementation. Figure 1 presents the four scenarios according to extreme conditions of these variables.



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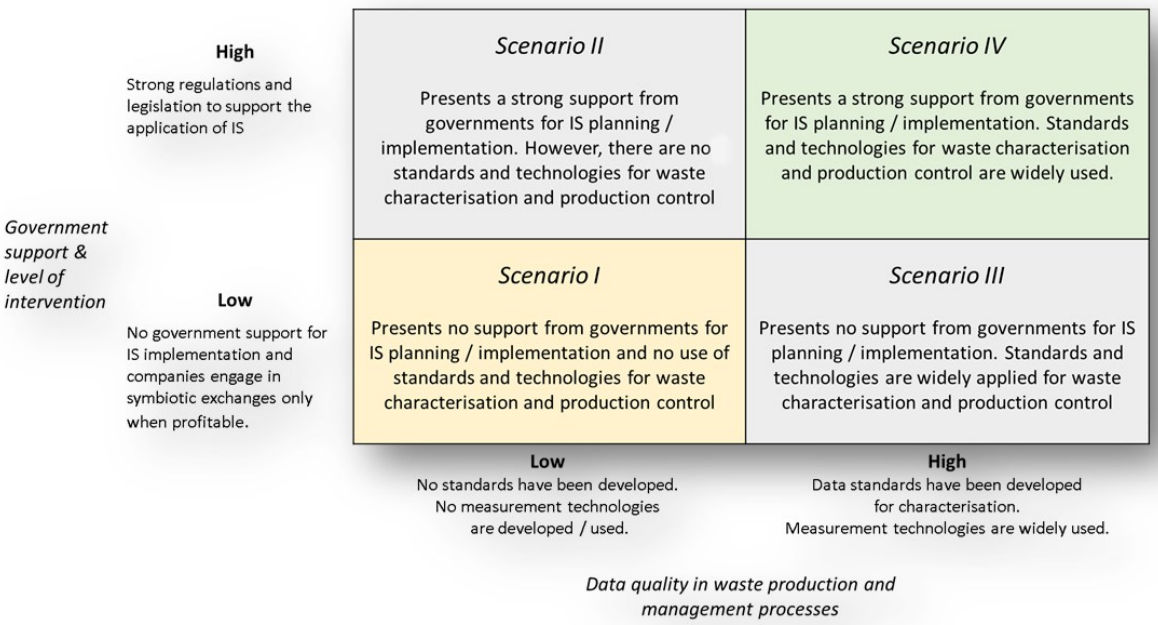


Figure 1. Contextual definition of IS scenarios

## *IS Scenario I*

*Context overview*

This scenario is framed in a context where there is no governmental support for IS implementation. Following this lack of support, there has been no public or private interest on the development of data standards for waste nor on the application of technologies for the measurement / control of waste data.

Individual manufacturing companies in the process industry encounter serious difficulties to identify physical waste that has the potential to create additional value for the company. Self-organised IS applications arise due to established relations between middle managers in companies that pursue environmentally-driven innovations. The realisation of IS applications is done through engaging with like-minded organisations and / or providing proof of economic viability for their self-identified exploitation opportunities. This self-motivated application of IS would struggle to receive resources, personnel or technologies from the top management if the balance between costs and benefits does not show its profitability, or at least evidence of being self-sustained.



*Scenario description*

Doroteya is the production manager of a manufacturing company within the process industry. The company has a strong focus on the environmental impact of their operations since its origin and has frequently implemented eco-innovations. Doroteya is continuously looking for opportunities to improve the manufacturing processes and create value for the company. She identified an increased waste stream during the last periodic review of the facilities, using a set of guidelines for "how to see waste". She is meeting the production line

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manager, Curie, to study the possibilities to eliminate or exploit that particular waste. They normally use a waste database and a set of tools to identify and evaluate the exploitation opportunities that potentially create more value for the company. The assessment is mainly made based on their experience, as they lack quality data from waste streams. They will need to justify economic viability to the company, if they want to get additional investment for the identified opportunity.

Depending on the type of exploitation opportunities that they identify, after the meeting Doroteya and Curie may contact one of their colleagues from their regional Engineers Society, as happened in previous cases, to share the opportunity idea with a manager of another manufacturing and try to work out a solution between the two companies. Case studies from the IS database help them to understand what exchanges have worked in the past. The data is limited due to the lack of overall support and engagement in IS, but Doroteya can use these to start conversations and ask sensible questions to her peers. They do not follow any structured way to approach each other and this will happen probably in the next meeting of the Engineers Society.

## *IS Scenario II*

*Context overview*

This scenario is framed in a context where EU governments have put in place strong regulations and legislation to support the implementation of IS. The support is provided at national level from the central government but also it is additionally backed up by local and regional regulations that provide focussed support, adapted for the particular characteristics of the locality or region. This support has not been followed by the development of data standards for waste processes, with neither the public nor private sector taking a lead. The regulations have not increased the knowledge on the application of technologies for the measurement and control of waste and the associated data challenges.

Manufacturing companies in the process industry are heavily encouraged by regulations to apply waste management processes and to find opportunities to create value from their physical waste. These companies can then access different sources provided by different governmental bodies to catalogue their physical waste. These documents include examples of potential exploitation opportunities to emphasize some applications already carried out in well-known case studies. Manufacturing companies would be able to identify some opportunities to comply with government regulations. Facilitated IS occurs frequently in this scenario as government support may be realised through emphasizing National Industrial Symbiosis Programmes (NISPs). Nevertheless, the lack of quality in waste data would be a barrier for obtaining the maximum value from the identified exchanges as they would not be able to efficiently characterise / quantify the different waste streams.



*Scenario description*

Doroteya is the production manager of a manufacturing company within the process industry. The company has a strong concern on the environmental impact of their operations since its origin and has frequently implemented eco-innovations. Lately, their focus has been

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drawn by government regulations for waste, and they seek to take advantage of government support to implement IS exchanges between different production processes of different companies. Doroteya identified an increased waste stream during the last periodic review of the facilities, using a set of guidelines for "how to see waste". She is meeting the production line manager, Curie, to study the possibilities to eliminate or exploit that particular waste. They normally use a waste database and a set of tools to identify opportunities (how the waste might be used and how new opportunities might be identified) and evaluate the exploitation opportunities to explore the potential value for the company. The assessment is mainly made based on their experience, as they lack quality data from waste streams.

Additional information to this assessment comes from government guidance documents that bring extra information on different types of waste. The established fees on landfill disposal of waste materials are an important dimension that they need to consider and that facilitates the discussion with the company investors, if they want to get additional investment for the identified opportunity.

Doroteya and other colleagues from the company are involved in a government initiative that tries to match together companies willing to share resources and participate in IS exchanges. She will bring the identified opportunity to the next meeting in order to identify a possible partner to develop IS together.

## *IS Scenario III*

*Context overview*

This scenario is framed in a context where there is no governmental support for IS implementation. In contrast to this lack of support from government through regulations or legislation, there has been a strong development of data standards for waste processes and a wide application of technologies for the measurement / control of waste data. The technological developments are built on sensor technology and IoT technology and have enormously increased the quality of the data available to companies for waste management.

Available standards for waste characterisation and the technologies developed to support waste management processes facilitate the engagement of manufacturing companies on IS planning. There are waste management systems widely available to effectively collect data on waste production rates and certain important parameters. Unfortunately, the lack of governmental support creates barriers to make the identified IS opportunities possible, as there are no regulations and legislations that favour waste material exchanges between companies. IS occur mainly internally, i.e. within the same organisation, as the waste streams remain under their own management and responsibility.



*Scenario description*

Doroteya is the production manager of a manufacturing company within the process industry. The company has a strong concern on the environmental impact of their operations since its origin and has frequently implemented eco-innovations. Doroteya is continuously

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looking for opportunities to improve the manufacturing processes and create value for the company. She identified an increased waste stream during the last periodic review of the facilities, using a set of guidelines for "how to see waste", and has immediately requested additional data from the waste monitoring system to better characterise this waste. She is meeting the production line manager, Curie, to study the possibilities to eliminate or exploit that particular waste. Sandra, the waste data manager, will join them to bring information to the meeting on waste characteristics. They normally use a waste database and a set of tools to identify opportunities and evaluate the exploitation opportunities that create more potential value for the company. The company has implemented a waste monitoring and control system that provides quality data of waste streams for evaluation purposes and that can support the exploitation phase for this opportunity. The assessment of opportunities is then informed by quality data from waste streams as well as by their own expertise. They will need to justify economic viability to the company if they want to get an additional investment for the identified opportunity.

Depending on the type of exploitation opportunities that they identify, after the meeting Doroteya and Curie may contact one of their colleagues from their regional Engineers Society, as happened in previous cases, to share the opportunity idea with a manager of another manufacturing company and try to work out a solution between the two companies. They do not follow any structured way to approach each other and this will happen probably in the next meeting of the Engineers Society.

### *IS Scenario IV*

*Context overview*

This scenario is framed in a context where EU governments have put in place strong regulations and legislation to support the implementation of IS. The support is provided at national level from the central government, but it is also additionally backed up by local and regional specific regulations that provide focussed support for the particular characteristics of the locality or region. Additionally, strong standards for waste processes have been developed and technologies for the measurement / control of waste data have been widely applied. The technological developments are built on sensor technology and IoT technology and have enormously increased the quality of the data available to companies for waste management.

Manufacturing companies in the process industry are heavily encouraged by regulations to apply waste management processes and to find opportunities to create value from their physical waste. These companies can then access different sources provided by different governmental bodies to catalogue their physical waste, integrated standards for waste characterisation and a broad variety of available technologies to facilitate waste management processes at factory level. It is common practice to apply technologies to monitor waste features and production rates in order to control the quantity and quality of waste as input to other processes. In this context, an increased number of IS applications will be performed both internally and in partnership with other companies.



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*Scenario description*

Doroteya is the production manager of a manufacturing company within the process industry. The company has a strong concern on the environmental impact of their operations since its origin and has frequently implemented eco-innovations. Lately, their focus has been emphasized by government regulations for waste and they take advantage of the government support to implement IS exchanges between different production processes of different companies. Doroteya identified an increased waste stream during the last periodic review of the facilities, using a set of guidelines for "how to see waste", and has immediately requested additional data from the waste monitoring system to better characterise this waste. She is meeting the production line manager, Curie, to study the possibilities to eliminate or exploit that particular waste. Sandra, the waste data manager, will join them to bring information to the meeting on waste characteristics. They normally use a waste database and a set of tools to identify opportunities and evaluate the exploitation opportunities that create more potential value for the company.

The company has implemented a waste monitoring and control system that provides quality data of waste streams for evaluation purposes and that can support the exploitation phase for this opportunity. The assessment of opportunities is then informed by quality data from waste streams as well as by their own expertise. Additional information to this assessment comes from government guidance documents that bring extra information on different types of waste. The established fees on landfill disposal of waste materials and heat and wastewater release to the environment are an important dimension that they need to consider and that facilitates the discussion with the company investors if they want to get an additional investment for the identified opportunity.

Doroteya and other colleagues from the company are involved in a government initiative that tries to match together companies willing to share resources and participate in IS exchanges. She will bring the identified opportunity to the next meeting in order to identify a possible partner to develop IS together. Additionally, the case study database informs Doroteya about the different types of relationships that can be effective under different circumstances.



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