CEN

WORKSHOP

AGREEMENT

CWA 17935

October 2022

ICS 07.120; 13.020.20

English version

Sustainable Nanomanufacturing Framework

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which is indicated in the foreword of this Workshop Agreement.

The formal process followed by the Workshop in the development of this Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN-CENELEC Management Centre can be held accountable for the technical content of this CEN Workshop Agreement or possible conflicts with standards or legislation.

This CEN Workshop Agreement can in no way be held as being an official standard developed by CEN and its Members.

This CEN Workshop Agreement is publicly available as a reference document from the CEN Members National Standard Bodies.

CEN and CENELEC members are the national standards bodies and national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Contents

Page

Foreword

This CEN Workshop Agreement (CWA 17935:2022) has been developed in accordance with the CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – A rapid prototyping to standardization" and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by a Workshop of representatives of interested parties on 2022-09-20, the constitution of which was supported by CEN following the public call for participation made on 2021-11-24. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

The final text of this CEN Workshop Agreement was provided to CEN for publication on 2022-09-26.

Results incorporated in this CWA received funding from the European Union's Horizon 2020 research and innovation programme, under Grant Agreements No 814581 [OASIS] and No 862330 [INNOMEN].

The following organizations and individuals developed and approved this CEN Workshop Agreement:

- Chairperson: Eng. MSc. Jesús López de Ipiña, Jesús (Tecnalia).
- Vice-Chairperson: Ms. Joséphine Steck (CEA).
- AcumenIST: Dr. Steffi Friedrichs.
- Adamant Composites Ltd.: Ms. Despoina Batsouli, Mr. Grigorios Koutsoukis and Dr. Antonios Vavouliotis.
- BioNanoNet Forschungsgesellschaft mbH: Mag. pharm., MSc. Susanne Resch and MSc. Clemens Wolf.
- CEA: Dr. Simon Clavaguera and Dr. Cécile Girardot.
- Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.: Dr. Benedikt Schug.
- IPC: Mr. Maudez Le Dantec.
- ISQ: Mr. João Laranjeira and Ms. Cristina Matos
- Laboratoire National de Métrologie et d'Essais (LNE): PhD. Georges Favre.
- Pleione Energy SA: Dr. Athanasios Masouras and Mrs. Dorela Hoxha.
- Tecnalia: Dr. José Luis Viviente.
- TMBK Partners: Mr. Pawel Duralek and Mr. Przemyslaw Kosmider.
- UNE: Mr. Fernando Machicado and Ms. Raquel Martínez Egido.
- Universidad de Castilla-La Mancha: Dr. Rafael Orlando Klee Morán, Professor María Luz Sánchez, Professor Paula Sánchez and MSc. Leticia Toledo Murcia.
- University of Patras: Dr. Stavros Tsantzalis and Professor Vassilis Kostopoulos.
- Sisteplant S.L.: Mr. Paul Gomendiourrutia.

Attention is drawn to the possibility that some elements of this document may be subject to patent rights. CEN/CENELEC policy on patent rights is described in CEN-CENELEC Guide 8 "Guidelines for

Implementation of the Common IPR Policy on Patent". CEN shall not be held responsible for identifying any or all such patent rights.

Although the Workshop parties have made every effort to ensure the reliability and accuracy of technical and nontechnical descriptions, the Workshop is not able to guarantee, explicitly or implicitly, the correctness of this document. Anyone who applies this CEN Workshop Agreement shall be aware that neither the Workshop, nor CEN, can be held liable for damages or losses of any kind whatsoever. The use of this CEN Workshop Agreement does not relieve users of their responsibility for their own actions, and they apply this document at their own risk. The CEN Workshop Agreement should not be construed as legal advice authoritatively endorsed by CEN/CENELEC.

Introduction

European manufacturing is determined to provide by 2030 a robust foundation for the economic, social and ecologically sustainable development of the European Union, which will contribute to increasing sustainability in a global context. It is also expected that both nanotechnology and sustainability, will be two important sources of differentiation and competitiveness for the European manufacturing industry in the global market.

Although different definitions are used for the concept of sustainable manufacturing, there is no official standardized one. The U.S. Department of Commerce [50] proposed in 2008 one of the first and most widely used definitions of sustainable manufacturing: "*the creation of manufactured products that use processes that are non-polluting, conserve energy and natural resources, and are economically sound and safe for employees, communities, and consumers*". This definition has supported other definitions such as those produced by the US EPA [51] or ASTM [43].

Despite the fact that the concept of sustainability has been traditionally associated with an environmental dimension, all these definitions highlight the three-dimensionality of sustainable manufacturing, that encapsulates three basic dimensions: social, environment and economy.

In the literature review, different relevant initiatives on sustainable manufacturing can be found: the European Commission (EC) [45] [46] [47] through the S3-Smart Specialization Platform [48], the US Department of Commerce [49] [50], the US Environmental Protection Agency [51], the OECD through the sustainable manufacturing toolkit [44], among others. Various methods, tools and metrics have been applied for sustainability performance assessment in manufacturing. In the field of standardization, several ISO standards, some of them adopted by CEN as European standards, address issues related to sustainability such as quality [1] [2] [7], environment [3] [4], safety [35], responsibility, social, governance, etc. Those can be applied to manufacturing processes to cover such sustainability items. In this regard, standards developed by ASTM - Subcommittee E60.13 on Sustainable Manufacturing [43] are of particular interest.

The sustainable manufacturing of nanotechnology supports the needs of the industry, contributes to the industrial policies of the EU and promotes the technological leadership of Europe. At the same time, it minimizes negative environmental impacts, conserves energy and natural resources, is safe for employees, communities, and consumers, and is economically sound.

Pilot Lines (PLs) are strategic instruments of the European Commission to bridge the "valley of death", and successfully introduce innovations based on Key Enabling Technologies (KETs) into the market. In particular, in the field of nanotechnology, they are the embryo of tomorrow's nano-manufacturing industry in Europe. Nanomanufacturing Pilot Lines (NPLs) are responsible for the potential impacts on sustainability (social, environmental, economic) that their nanomanufacturing activities can produce.

The incorporation of sustainability requirements in these NPLs, from the first stages of design and operation of the new processes, constitutes a proactive strategy to ensure equally sustainable future commercial nanomanufacturing processes. Consequently, there is a need to define requirements to guarantee the environmental, social and economic sustainability of these NPLs, considering at the same time their embryonic and pre-commercial nature. This requires simple sustainability management schemes easy to use and apply.

In this context, this document inserts the concept of sustainable manufacturing into the field of nanotechnology, by proposing a new simplified conceptual framework to implement sustainability in NPLs and evaluate their sustainable manufacturing performance. Our ambition is to contribute to the deployment of more efficient and sustainable nano-manufacturing processes that enable the manufacture of safer and more sustainable nanomaterials and nanoproducts, as the European Commission recently pointed out.

The Sustainable Nanomanufacturing Framework (SNF) described in this document is based on the one developed by the H2020 OASIS project OASIS "Open Access Single entry point for scale-up of Innovative

Smart lightweight composite materials and components". The OASIS model is a simple and user-friendly screening tool designed to carry out the initial diagnosis, define the improvement plans and evaluate the sustainability and evolution of NPLs. This framework has been tested in 12 NPLs of the OASIS project (GA 814581) and 7 NPLs of the INNOMEM project (GA 862630).

Annex A shows, using an example based on the OASIS NPL4, the practical application of the 10-step SNF evaluation procedure described in this document. Annex B of this document shows the results corresponding to the diagnosis and planning stages of the Plan-Do-Check-Act (PDCA) cycle in four of the 12 NPLs of OASIS Subsequently, the H2020 INNOMEM project "Open Innovation Test Bed for nano-enabled Membranes", also used the model to assess the sustainability of the NPLs incorporated in its manufacturing ecosystem. Annex C of this document shows the results corresponding to the initial diagnosis and planning stages in two NPLs of this last project.

The OASIS project has developed a simple software based on MS Excel (OASIS-SNF Tool) to automate the practical application of the 10-step SNF evaluation procedure. This tool has been used by the project to diagnose, implement, monitor and re-evaluate management practices and sustainability results in NPLs, in conformity with the requirements of the SNF model. It is envisaged that a new version of the OASIS-SNF Tool will be publicly available at the website of OASIS (https://project-oasis.eu/) at the end of the project (November 2022).

The SNF was initially conceived and designed as a resilient model to be used in the broad scope of sustainable manufacturing (SM), for any manufacturing process. However, given the scope of the OASIS project, the primary model was later customized to be used in the field of sustainable nanomanufacturing (SN).

1 Scope

This document describes and specifies the requirements of a simplified Sustainability Nanomanufacturing Framework (SNF) for sustainability management in Nanomanufacturing Pilot Lines (NPLs), appropriate to their size, management capabilities and sustainability priorities.

The SNF sets up the basic requirements for a screening methodology to quicky assess the sustainability of a NPL. It provides guidance for diagnosis, implementation, and monitoring, to proactively improve nano-sustainability performances in NPLs, considering its sustainability management and results.

The model can be used by NPLs to achieve its intended outcomes in the field of nano-sustainability.

The SNF is intended to be applied to any NPL regardless of its size, type and activities. Similarly, the model could be scaled to manage the sustainability of a manufacturing area/plant that integrates multiple NPLs.

This document can be used in whole or in part to systematically improve the sustainability in NPLs.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 General

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at https://www.electropedia.org/

3.2 Terms related to nanotechnology

3.2.1
nano-enabled product
product exhibiting function or performance only possible with nanotechnology.

Note 1 to entry: finished goods incorporating nanotechnology.

Note 2 to entry: term customized from ISO/TS 80004-1:2015 [36].

3.2.2
nano-intermediate
intermediate product with nanoscale features.

3.2.3
nanomanufacturing pilot line
pilot line conceived for the manufacture of nanomaterials, nano-intermediates or nano-enabled products.

3.2.4
nanomanufacturing process
ensemble of activities to intentionally synthesize, generate or control nanomaterials, or fabrication steps in the nanoscale, for commercial purposes.

[SOURCE: ISO/TS 80004-1:2015, definition 2.12] [36]

3.2.5
nanomaterial
material with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale.

Note 1 to entry: This generic term is inclusive of nano-object and nanostructured material.

Note 2 to entry has been deleted.

[SOURCE: ISO/TS 80004-1:2015, definition 2.11] [36]

3.2.6
NOAA
nano-objects, and their agglomerates and aggregates.

Note 1 to entry: NOAAs include structures with one, two or three external dimensions in the nanoscale, which might be spheres, fibres, tubes and others as primary structures. NOAAs can consist of individual primary structures in the nanoscale and aggregated or agglomerated structures, including those with sizes larger than 100 nm.

[SOURCE: ISO/DIS 80004-1, definition 2.11] [37]

3.3 Terms related to production and manufacturing

3.3.1
process
set of interrelated or interacting activities that use inputs to deliver an intended result.

[SOURCE: ISO 9000:2015, definition 3.4.1 (without notes)] [1]

3.3.2
manufacturing process
structured set of activities involving a flow and/or transformation of material, information, energy, or any other element in a manufacturing area.

[SOURCE: ISO 20140-1:2019, 3.14] [17]

3.3.3
pilot line
the physical infrastructure and equipment needed to produce small series of pre-commercial products.

[SOURCE: Pilot Production in Key Enabling Technologies, EC 2017] [47]

3.4 Terms related to sustainability

3.4.1
economic aspect
element of an organization's activities or products or services that interacts or can interact with the economy.

[SOURCE: ISO 23434-1:2021] [32]

3.4.2
economic sustainability
ability to provide sustainable, successful places in an economic context.

Note 1 to entry: Economic considerations include employment, competitiveness, wealth and distribution, welfare, accounting and regulation.

[SOURCE: ISO 17889-1:2021] [15]

3.4.3
environmental aspect
element of an organization's activities or products or services that interacts or can interact with the environment.

[SOURCE: EN ISO 14001:2015] [3]

3.4.4
environmental sustainability
state in which the ecosystem and its functions are maintained for the present and future generation.

[SOURCE: ISO 17889-1:2021] [15]

3.4.5
social aspect
element of an organization's activities or products or services that interacts or can interact with society or quality of life.

[SOURCE: ISO 23434-1:2021] [32]

3.4.6
social sustainability
ability to provide sustainable, successful places in a social context.

Note 1 to entry: Social sustainability combines design of the physical realm with design of the world, infrastructure to support social and cultural life, provides social amenities, systems for citizen engagement and spaces for people and places to evolve.

[SOURCE: ISO 17889-1:2021] [15]

3.4.7
sustainability
state of the global system, including environmental, social and economic aspects, in which the needs of the present are met without compromising the ability of future generations to meet their own needs.

Note 1 to entry: The environmental, social and economic aspects interact, are interdependent and are often referred to as the three dimensions of sustainability.

Note 2 to entry: Sustainability is the goal of sustainable development (3.2).

[SOURCE: ISO Guide 82:2019, definition 3.1] [40]

3.4.8
sustainable development
development that meets the environmental, social and economic needs of the present without compromising the ability of future generations to meet their own needs.

Note 1 to entry: Derived from the Brundtland Report [18].

[SOURCE: ISO Guide 82:2019, definition 3.2] [38]

3.4.9
sustainability aspect
aspect of an activity or goods or services that, during the life cycle of the activity, or goods or services, is related to sustainability, positively or negatively.

[SOURCE: ISO 20400:2017] [18]

3.4.10
sustainability dimension
Each of the three pillars on which the concept of sustainability is based: environmental, economic and social.

3.4.11
sustainability indicator
indicator related to economic, environmental or social impacts.

[SOURCE: ISO 21929-1:2011, 3.33] [22]

3.4.12
sustainability item
Each of the sustainability aspects that build the three sustainability dimensions.

3.4.13
sustainability KPI
key performance indicator that represents sustainability performance.

3.4.14
sustainability objective
intent to achieve global sustainability, resulting from the sustainability policy that an enterprise or destination sets itself to achieve, being quantified whenever possible.

[SOURCE: ISO 23405:2022, 3.1.5] [31]

3.4.15
sustainability performance
combination of environmental performance, social performance and economic performance of an organization.

Note 1 to entry: measurable results related to sustainability aspects.

[SOURCE: ISO 21931-2:2019(en), 3.30 modified – Note 1 adapted.] [25]

3.4.16
sustainability management
set of coordinated activities within an organization related to its sustainability aspects.

3.4.17
sustainability requirement
requirement related to sustainability.

3.5 Terms related to management

3.5.1
baseline
reference basis for comparison against which performance is monitored and controlled.

[SOURCE: ISO/TR 21506:2018, 3.5] [19]

3.5.2
continual improvement
recurring activity to enhance performance.

[SOURCE: EN ISO 9000:2015, without notes] [1]

3.5.3
indicator
quantitative, qualitative or binary variable that can be measured, calculated or described, representing the status of operations, management, conditions or impacts.

[SOURCE: 14050:2020] [5]

3.5.4
key performance indicator
indicator of performance deemed by an organization to be significant and giving prominence and attention to certain aspects of operations, management, conditions or impacts.

Note 1 to entry: The KPIs are derived directly from, or through an aggregation function of, physical measurements, data and/or other KPIs.

[SOURCE: ISO 14050:2020; Note 1 to entry from ISO 22400-1:2014, 2.1.5] [5] [6] [27]

3.5.5
lagging indicator
metric that gives an indication of past performance.

[SOURCE: ISO 10014:2021] [7]

3.5.6
leading indicator
metric that gives an indication of expected performance.

[SOURCE: ISO 10014:2021] [7]

3.5.7
legal requirements and other requirements
legal requirements that an organization has to comply with and other requirements that an organization has to or chooses to comply with.

[SOURCE: ISO 45001:2018, without notes] [35]

3.5.8
management
coordinated activities to direct and control an organization.

[SOURCE: EN ISO 9000:2015, without notes] [1]

3.5.9
management system
set of interrelated or interacting elements of an organization to establish policies and objectives, and processes to achieve those objectives.

[SOURCE: EN ISO 9000:2015, without notes] [1]

3.5.10
nonconformity
non-fulfilment of a requirement.

[SOURCE: EN ISO 9000:2015, without notes] [1]

3.5.11
regulatory requirement
obligatory requirement specified by an authority mandated by a legislative body.

[SOURCE: EN ISO 9000:2015] [1]

3.5.12
requirement
need or expectation that is stated, generally implied or obligatory.

[SOURCE: EN ISO 9000:2015, without notes] [1]

3.5.13
strategy
plan to achieve a long-term or overall objective.

[SOURCE: EN ISO 9000:2015] [1]

3.6 Abbreviated terms

EHS	Environment, Health and Safety
IP	Improvement Plan
KPI	Key Performance Indicator
NEP	Nano-Enabled Product
NM	Nanomaterial
NPL	Nanomanufacturing Pilot Line
NQA	Number of Question
OHS	Occupational Health and Safety
PDCA	Plan-Do-Check-Act (continuous improvement cycle)
PL	Pilot Line
QES	Quality, Environment and Safety
SBQ	Score By question
SD	Sustainability Dimension

SDG	Sustainable Development Goal
SDW	Sustainability Dimension Weight
SI/SA	Sustainability Item/ Sustainability Aspect
SIW	Sustainability Item Weight
SM	Sustainability Management
SNF	Sustainability Nanomanufacturing Framework
SNFI	Sustainability Nanomanufacturing Index
SR	Sustainability Results
TMS	Total Model Score
TSDS	Total Sustainability Dimension Score
TSDSW	Total Sustainability Dimension Score (weighted)
TSIS	Total Sustainability Item Score
TSISW	Total Sustainability Item Score (weighted)

4 Definition of the Sustainable Nanomanufacturing Framework (SNF)

4.1 Introduction

The SNF is a simplified framework to manage and improve nano-sustainability for significant aspects in the NPLs and other nanomanufacturing processes. The model deploys the three traditional Sustainability Dimensions (SDs): Social, Environment and Economy. Each SD is divided into several Sustainability Items (SIs), as shown in Table 1.

The SNF allows the assessment and diagnose of the starting position of a nanomanufacturing pilot line with respect to the SNF model, at two levels:

1) Sustainability management practices; and

2) Sustainability results, by using Key Performance Indicators (KPIs) to measure results.

The result of the diagnose is used to elaborate the corresponding Sustainability Improvement Plan (SIP) for the implementation/improvement of the SNF in the nanomanufacturing pilot line.

The SNF is used to monitor the progress of sustainability in the nanomanufacturing processes through a customizable dashboard, that shows the two pillars (management practices and results) in two radar diagrams, and a Sustainable Nanomanufacturing Index (SNFI). This dashboard allows intuitive visualization of the starting values and the proposed improvement values for the period considered, as well as of their evolution over time.

The SNF is nano-specific and applies to “nano” sustainability aspects. The model also includes some non-nano specific SIs, such as energy, economic performance, quality and digitalization, which are especially relevant for scaling NPLs, for the future commercial manufacture of nanomaterials and nanoproducts. NPLs can customize the SNF according to the SDs and SIs selected as priorities. In addition, the SNF can be expanded by adding new SIs in each of the three SDs.

The model considers compliance with regulatory requirements applicable to each nano-sustainability issue. The simplicity of the model requires low dedication of resources for its diagnosis, implementation, and continuous improvement. The framework is applicable to any NPL regardless of its size, type and activities. The model can be used by NPLs to achieve its intended outcomes in the field of nano-sustainability during successive stages of the innovation process (TRLs).

The adoption of the SNF is intended to enable NPLs to manufacture sustainably their products (NMs, nano-intermediates, NEPs), manage properly their sustainability priorities, and improve continually their sustainability performance.

The model meets the following basic design specifications:

a) Nano-oriented. The model focuses on the nano-sustainability aspects of nanoprocesses, and is especially aimed at its implementation in NPLs.

b) Customizable. The model is customizable to monitor and manage those nano-sustainability aspects identified as significant by NPLs.

c) Continuous improvement. The model has been designed to implement continuous improvement in the field of nano-sustainability in NPLs.

d) Simple, easy to deploy and use. The model is easily implementable in NPLs and monitoring and optimization is supported by KPIs.

e) Progressive. The model is based on progressive scores, KPIs and improvement baselines that allow monitoring the continuous improvement of the sustainable behaviour of the NPL.

f) Involving regulatory compliance. The model considers compliance with regulatory requirements (and other relevant requirements) applicable to SIs.

g) Aligned with sustainability standards. The design of the model is conceptually supported by the existing standards on management, sustainability, sustainability in manufacturing and relevant nanotechnological aspects. In particular, it is aligned with management practices deployed by management systems standards for quality, environment, and safety and health at work (e.g. EN ISO 9001 [2], EN ISO 14001 [3], ISO 45001 [35]).

h) Cost effective. The simplicity of the model ensures the need of a low level of resources and dedication of the NPL for its diagnosis, implementation and continuous improvement.

4.2 Pillars, basic architecture and customization

The SNF evaluates nano-sustainability in NPLs from two points of view:

1) **Sustainability Management**, which refers to the management practices implemented by the NPL to manage its sustainability priorities (SDs and SIs).

2) **Sustainability Results**, which refers to the results obtained by the NPL with the implementation of sustainability management practices, measured by Key Performance Indicators (KPIs).

The SNF model is based on the three traditional Sustainability Dimensions (SDs):

- SD1. Social,
- SD2. Environmental, and
- SD3. Economic

At the same time, each SD is divided into several Sustainability Items (SIs).

The Social dimension (SD1) deploys a single SI:

- SI 1.1 Nano-OHS

The Environmental dimension (SD2) deploys five SIs:

- SI 2.1 Nanomaterials and nanoproducts,
- SI 2.2 Nano-air emissions,
- SI 2.3 Nano-wastewaters,
- SI 2.4 Nano-wastes, and
- SI 2.5 Energy

Finally, the Economic dimension (SD3) deploys three SIs:

- SI 3.1 Economic performance,
- SI 3.2 Quality, and
- SI 3.3 Digitization.

Thus, the initial array of the model consists of three SDs and nine SIs (see Table 1). In the future, the model can be expanded, incorporating new SIs in the three SDs considered.

Table 1 — General architecture of the SNF model showing the three Sustainability Dimensions (SDs) and the corresponding Sustainability Items (SIs) considered by each of them

Sustainability Dimension (SD)	Sustainability Item (SI)
1. SOCIAL	1.1 Nano-OHS
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts
	2.2 Nano-air emissions
	2.3 Nano-wastewaters
	2.4 Nano-wastes
	2.5 Energy
3. ECONOMIC	3.1 Economic performance
	3.2 Quality
	3.3 Digitization

The scope of the SNF can be customized according to the sustainability priorities of the NPL, by selecting those SIs that are significant within each of the three sustainability dimensions considered. Therefore, some SIs can be found relevant and others can be discarded (see example in Annex A).

4.3 Evaluation of the Sustainability Management of the NPL

4.3.1 Sustainability management diagnosis

Each of the SIs is evaluated by means of a customized questionnaire. Thus, nine specific questionnaires, one per SI, have been included in the model. Each questionnaire contains 10 questions, and each question can be scored from 0 to 10 points, according to the evaluator's criteria, in view of the available evidence provided by the NPL. If the NPL has not implemented any practice related to any of the questions of the set of 10 questions, the score of that question will be 0.

Each questionnaire can rate the current status of a selected SI and propose an improved expected future punctuation. Using all these scores, the model displays two baselines: a) the Sustainability Management-Current Baseline (the current situation of the NPL) and b) the Sustainability Management-Target Baseline (the future expected situation of the NPL).

The total score of each SI (Current Baseline) is the summatory of all its questions. In the same way, the Target Baseline, and the improvement percentage (the difference between the two baselines) is calculated as the summatory of scores recorded in their respective questions.

The maximum score per questionnaire is 100 points. Thus, the nine SIs can be easily displayed on percentage scales. The nine questionnaires and 10 questions per SI are shown in Tables 2 to 10, as well as the way to register the sustainability management diagnosis described below.

Table 2 — Questionnaire to evaluate the Sustainability Item "Nano-OHS" (SI 1.1), within the SOCIAL Sustainability Dimension (SD1)

SD1.- Social								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
1.1 OHS risks	1.1.1	Basic managerial practices about the risks to the safety and health of workers derived of the use/handling of nanomaterials and nanoproducts (OHS nanorisks, such as e.g. explosion, fire, exposure by inhalation, etc) have been identified.						
	1.1.2	Hot spots connected with OHS-nanorisks have been identified						
	1.1.3	Regulatory requirements on OHS-nanorisks have been identified and are known						
	1.1.4	OHS-nanorisks have been evaluated, including potential emergency situations. Risk assessment is permanently updated with the evolution of working conditions and new technologies.						
	1.1.5	Specific preventive and protective measures against nanorisks have been implemented according to risk assessment and following the hierarchical STOP approach (Substitution, Technological, Organizational and PPEs), and are properly maintained and periodically reviewed to ensure maximum effectiveness.						
	1.1.6	In particular, PPEs (clothing, masks, gloves, etc) have been appropriately selected, supplied to workers, used and properly maintained.						
	1.1.7	Workers have been consulted, informed and appropriately trained about nanorisks.						
	1.1.8	KPIs have been established to monitor the management of OHS-nanorisks						
	1.1.9	A systematic management of OHS-nanorisks has been deployed (objectives, organization, documentation)						

SD1.- Social								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
	1.1.10	Improvement objectives for the management of OHS-nanorisks have been established.						
	TOTAL							

Table 3 — Questionnaire to evaluate the Sustainability Item "Nanomaterials and nanoproducts" (SI 2.1), within the ENVIRONMENTAL Sustainability Dimension (SD2)

SD2.- Environmental								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
2.1 Materials and products	2.1.1	Basic managerial practices with nanomaterials and nanoproducts have been identified.						
	2.1.2	Nanomaterials and nanoproducts streams and hot spots have been identified.						
	2.1.3	Nanomaterials and nanoproducts have been classified by typologies.						
	2.1.4	Quantities of nanomaterials and nanoproducts consumed/produced have been determined.						
	2.1.5	Regulatory requirements on nanomaterials and nanoproducts have been identified and are known.						
	2.1.6	Safety Data Sheets (SDSs) on nanomaterials and nanoproducts are available.						
	2.1.7	Nanomaterials and nanoproducts are used/handled according to instructions provided by SDSs.						
	2.1.8	KPIs have been established to monitor the management of nanomaterials and nanoproducts						
	2.1.9	A systematic management of nanomaterials and nanoproducts has been deployed (objectives, organization, documentation), including the efficiency of use and its substitution by others less dangerous.						
	2.1.10	Improvement objectives for the management of nanomaterials and nanoproducts have been established						
	TOTAL							

Table 4 — Questionnaire to evaluate the Sustainability Item "Nano-air emissions" (SI 2.2), within the ENVIRONMENTAL Sustainability Dimension (SD2)

SD2.- Environmental								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
2.2 Air emissions	2.2.1	Basic managerial practices with nano-air emissions have been identified.						
	2.2.2	Nano-air emissions streams and hot spots have been identified.						
	2.2.3	Nano-air emissions have been classified by typologies.						
	2.2.4	Nano-air emissions have been quantified						
	2.2.5	Regulatory requirements on nano-air emissions have been identified and are known.						
	2.2.6	Equipment and systems for nano-air emissions prevention and control, have been implemented and are properly maintained and periodically reviewed, to ensure maximum effectiveness.						
	2.2.7	Periodic assessment and/or measurement of nano-air emissions has been established						
	2.2.8	KPIs have been established to monitor the management of nano-air emissions						
	2.2.9	A systematic management of nano-air emissions has been deployed (objectives, organization, documentation)						
	2.2.10	Improvement objectives for the management of nano-air emissions have been established						
	TOTAL							

Table 5 — Questionnaire to evaluate the Sustainability Item "Nano-wastewaters " (SI 2.3), within the ENVIRONMENTAL Sustainability Dimension (SD2)

SD2.- Environmental								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
2.3 Wastewaters	2.3.1	Basic managerial practices with nano-wastewaters have been identified.						
	2.3.2	Nano-wastewaters streams and hot spots have been identified.						
	2.3.3	Nano-wastewaters have been classified by typologies.						
	2.3.4	Nano-wastewaters flows have been quantified						
	2.3.5	Regulatory requirements on nano-wastewaters have been identified and are known.						
	2.3.6	Equipment and systems for nano-wastewaters prevention and control, have been implemented and are properly maintained and periodically reviewed, to ensure maximum effectiveness.						
	2.3.7	Periodic assessment and/or measurement of nano-wastewater has been established						
	2.3.8	KPIs have been established to monitor the management of nano-wastewaters						
	2.3.9	A systematic management of nano-wastewaters has been deployed (objectives, organization, documentation)						
	2.3.10	Improvement objectives for the management of nano-wastewaters have been established						
	TOTAL							

Table 6 — Questionnaire to evaluate the Sustainability Item "Nano-wastes" (SI 2.4), within the ENVIRONMENTAL Sustainability Dimension (SD2)

SD2.- Environmental								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
2.4 Wastes	2.4.1	Basic managerial practices with nano-wastes have been identified.						
	2.4.2	Nano-wastes streams and hot spots have been identified.						
	2.4.3	Nano-wastes have been classified by typologies.						
	2.4.4	Nano-wastes flows have been quantified						
	2.4.5	Regulatory requirements on nano-wastes have been identified and are known.						
	2.4.6	Nano-wastes management has been established with accredited waste managers						
	2.4.7	Equipment and systems for nano-wastes prevention and control, have been implemented and are properly maintained and periodically reviewed, to ensure maximum effectiveness.						
	2.4.8	KPIs have been established to monitor the management of nano-wastes						
	2.4.9	A systematic management of nano-wastes has been deployed (objectives, organization, documentation)						
	2.4.10	Improvement objectives for the management of nano-wastes have been established						
	TOTAL							

Table 7 — Questionnaire to evaluate the Sustainability Item "Energy" (SI 2.5), within the ENVIRONMENTAL Sustainability Dimension (SD2)

SD2.- Environmental								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
2.5 Energy	2.5.1	Basic managerial practices (non-systematic) with energy have been identified						
	2.5.2	Energy streams (electricity, NG, LPG, steam, etc) and consumption hot spots have been identified.						
	2.5.3	Energy consumption has been evaluated						
	2.5.4	Regulatory and other energy requirements have been identified and are known						
	2.5.5	An energy monitoring systems has been established						
	2.5.6	Energy efficient equipment and facilities have been implemented and are properly operated and periodically maintained						
	2.5.7	Workers have been appropriately trained on environmental aspects related to energy and on the proper operation and maintenance of equipment and systems						
	2.5.8	Energy is managed according to specific instructions and/or procedures						
	2.5.9	A systematic management of energy has been deployed (objectives, organization, documentation).						
	2.5.10	KPIs to monitor and improve the management of energy have been established						
	TOTAL							

Table 8 — Questionnaire to evaluate the Sustainability Item "Economic performance" (SI 3.1), within the ECONOMIC Sustainability Dimension (SD3)

SD3.- Economic								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
3.1 Economic performance	3.1.1	Have you a established costing system?						
	3.1.2	Do you evaluate your product cost based on the costing system?						
	3.1.3	Do you measure the equipment efficiency?						
	3.1.4	Have you established some equipment improvement system?						
	3.1.5	Dou you measure the labour productivity?						
	3.1.6	Have you established some labour improvement system?						
	3.1.7	Have you done a benchmarking of your raw materials prices?						
	3.1.8	Do you measure the energy efficiency?						
	3.1.9	Have you established some energy efficiency improvement system?						
	3.1.10	Have you done a benchmarking of your final products prices?						
	TOTAL							

Table 9 — Questionnaire to evaluate the Sustainability Item "Quality" (SI 3.2), within the ECONOMIC Sustainability Dimension (SD3)

SD3.- Economic								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
3.2 Quality	3.2.1	Do you know the quality parameters that assure your products functionality?						
	3.2.2	Do you measure these quality parameters in line?						
	3.2.3	Do you keep the traceability of the products you send to the customers?						
	3.2.4	Do you have any improvement plan to reduce the defective levels?						
	3.2.5	Do you keep the traceability of your incoming materials and manufactured products?						
	3.2.6	Have you established a quality control for the incoming raw materials and consumables?						
	3.2.7	Have you an agreed quality system with your suppliers?						
	3.2.8	Do you control the fulfilment of these agreements?						
	3.2.9	Do you have an established procedure to solve internal and external non-conformities?						
	3.2.10	Do you have implemented any quality standards system (EN ISO 9001, …)?						
	TOTAL							

Table 10 — Questionnaire to evaluate the Sustainability Item "Digitalization" (SI 3.3), within the ECONOMIC Sustainability Dimension (SD3)

SD3.- Economic								
Item	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Impro-vement rate**
3.3 Digitization	3.3.1	Are your machines controlled by PLC`s?						
	3.3.2	Is the process information registered manually or automatically?						
	3.3.3	Are your machines connected to the company intranet?						
	3.3.4	Do you have an ERP (Enterprise Resource Planning) system?						
	3.3.5	Do you have a MES (Manufacturing Execution System) for plant management (work orders, traceability, OEE, people presence, …)?						
	3.3.6	Do you have a CMMS (Computerized Maintenance Management System)?						
	3.3.7	Do you have a PLM (Product Lifecycle Management)?						
	3.3.8	Do you have any simulation software?						
	3.3.9	Have you any predictive system (for predictive maintenance, for predictive delivery dates, …)?						
	3.3.10	Have you implemented any machine learning system that relates quality with process parameters?						
	TOTAL							

4.3.2 Sustainability management calculations

The model's total score is standardized to 300 points, 100 points per each of the three SDs, as with the SIs.

A Sustainability Nanomanufacturing Index (SNFI), has been proposed as the arithmetic mean (%) of the three SDs. This algorithm can be modified if necessary.

Table 11 summarizes the main scores, weights and calculations to parameterize Sustainability Management with the SNF.

The "Total Sustainability Item Score (TSIS)" of each relevant SI is calculated by the summatory of the scores of each of its 10 NQA. Therefore, the maximum TSIS value for any SI is 100 points, which allows all SI to be displayed on a percentage scale:

$$TSIS = \sum_{n=1}^{10} NQA_n = 100$$

As there are 9 SIs, and the maximum TSIS value for each SI is 100 points, the "Total Model Score (TMS)" is therefore 900 points:

$$TSIS = \sum_{n=1}^{9} TSIS_n = 900$$

Subsequently, the TSISs calculated for each SD are weighted by a specific weight, the Sustainability Item Weight (SIW).

$$TSISW = TSIS * SIW$$

In the SNF standard model, the total value of SWI for all relevant SI integrated in the same SD is 1. Therefore, this value has to be proportionally divided into the number of relevant SIs of each SD.

The default Sustainability Item Weight (SIW) is the following:

- Social SD (SD1). As it has only 1 SI, its SIW is 1
- Environmental SD (SD2). As it has 5 SIs, if all SIs are relevant, each SI has a SIW of 0,20, i.e. 1/5 .
- Economic SD (SD3). As it has 3 SIs, if all SIs are relevant, the SIW of each SI is 0,33/0,34, i.e. 1/3.

These weights are used to standardize the scores of the original model into percentage metrics, and thus build baselines (Current and Target) easily visualized in the plots. If necessary, these weights can be modified due to the relevance of any specific SI in the model for the specific NPL.

NOTE If a SI is not relevant, it is not considered. Likewise, if a new SI is defined and deemed relevant, the SIW has to be adapted to the actual number of relevant SI considered for each SD.

Table 11 — Maximum scores, weights and calculations to build the baselines of Sustainability Management, and the Sustainability Nanomanufacturing Index (SNFI) (see example in Annex A)

Sustainability Dimension (SD)	Sustainability Item (SI)	Current Baseline/Target Baseline							
		Number of questions to be Answered (NQA)	Score by question (SBQ)	Total SI Score (TSIS)	SI Weighting (SIW)	Total SI Score Weighted (TSISW)	Total SD Score (TSDS)	SD Weighting (SDW)	Sustainable Nano-manufacturing Index (SNFI)
1. SOCIAL	1.1 Nano-OHS	10	10	**100**	1,00	100	**100**	0,33	**33**
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts	10	10	**100**	0,20	20	**100**	0,33	**33**
	2.2 Nano-air emissions	10	10	**100**	0,20	20			
	2.3 Nano-wastewaters	10	10	**100**	0,20	20			
	2.4 Nano-wastes	10	10	**100**	0,20	20			
	2.5 Energy	10	10	**100**	0,20	20			
3. ECONOMIC	3.1 Economic performance	10	10	**100**	0,34	34	**100**	0,34	**34**
	3.2 Quality	10	10	**100**	0,33	33			
	3.3 Digitization	10	10	**100**	0,33	33			
Total		90		**900**	3	300	**300**	1	**100**

Note: the weights (SIW, SD) are used to standardize the scores of the original model into percentage metrics, in order to construct baselines (Current and Target) and an SNFI index, easily visualized by graphs.

Then, the "Total Sustainability Dimension Score" (TSDS) is calculated as the sum of the Total Sustainability Item Scores (weighted) (TSISW) that make up the SD considered.

$$TSDS_m = \sum_{n=1}^{n} TSISW_{m.n}$$

Considering the three dimensions:

$$TSDS_{SOCIAL} = \sum_{n=1}^{1} TSISW_{1.n} = \left(TSISW_{1.1}\right)$$

$$TSDS_{ENVIRONMENTAL} = \sum_{n=1}^{5} TSISW_{2.n} = \left(TSISW_{2.1} + TSISW_{2.2} + TSISW_{2.3} + TSISW_{2.4} + TSISW_{2.5}\right)$$

$$TSDS_{ECONOMIC} = \sum_{n=1}^{3} TSISW_{3.n} = \left(TSISW_{3.1} + TSISW_{3.2} + TSISW_{3.3}\right)$$

Consequently, the model's total score is now standardized to 300 points, 100 points per each of the three SDs. Thus, the three SDs can be easily visualized on a simple percentage scale.

In order to calculate the final **SNF index (SNFI)** on a percentage scale, the TSDS calculated for each SD are weighted again with a second specific weight (SDW). In the current model, the total value of SDW ("1") has been proportionally divided among the three SDs it displays. Therefore, the weight of each SD is 0,33 (SDW/3), assuming that each of the three SDs has the same relevance in the sustainability model (one third of the global one). If necessary, this weight (SDW) can be modified to reinforce the visibility of a specific SD in the model.

Similarly to the previous weightings, the TSDS of each SD is weighted by its corresponding weight (SDW), and the SNFI index is calculated as the sum of the three weighted TSDSWs:

$$TSDSW = TSDS * SDW$$

$$SNFI = \sum_{n=1}^{3} TSDSW_n = \left(TSDSW_{SOCIAL} + TSDSW_{ENVIRONMENTAL} + TSDSW_{ECONOMIC}\right)$$

Therefore, the SNFI is the arithmetic mean (%) of the 3 SDs. Based on SNFI, a first classification of the degree of sustainability of the NPL has been proposed in Table 12.

Table 12 — Classification of the degree of sustainability of NPLs, based on the SNF Index (SNFI)

SNFI (%)	Sustainability Level
0-15	Not sustainable
15-30	Little sustainable
30-50	Fairly sustainable
50-65	Sustainable
65-85	Very sustainable
85-100	Highly sustainable

Regarding the Target Baseline for improving the Sustainability Management in the NPL, the values entered in the improvement part of the questionnaires are exported to the calculation of the new SIs. Subsequently, the model uses the same calculation routine described above to calculate the improvement values of the SDs and the SNFI.

4.4 Evaluation of the Sustainability Results using KPIs

The SNF evaluates sustainability results of PLNPLs through KPIs. The model requires defining at least one KPI per each SI selected by the NPL, to establish the Sustainability Results - Current Baseline. To calculate the Sustainability Results - Target Baseline, the framework requires an improvement percentage to be established for each of the KPIs selected by the NPL.

The framework proposes a list of KPIs (see Table 13) where NPLs can select those KPIs that best suit their needs. However, NPLs are free to define and customize any other KPI, not included in the list, that could be more robust and/or feasible to monitor their sustainability results. Each KPI is defined by a simple document, according to the format established by ISO 22400-2 [28].

The Sustainability Results - Current Baseline is built with the current values of selected KPIs. Similarly, the Target Baseline is built with the expected values for the same KPIs. The value of the KPI target (KPIt) can be established directly or calculated from a percentage improvement ratio (I) with respect to the KPI current (KPIc), as follows:

$$KPIt = KPIc * (1 + I / 100)$$

Table 13 — Non-exhaustive list of Key Performance Indicators (KPIs) for monitoring Sustainability Items (SIs)

SD	SI	KPI	
		Leading KPI	**Lagging KPI**
1. SOCIAL	1.1 Nano-OHS	1.1 Risk assessments on nanorisks completed or reviewed 1.2 Number of inspections/audits to the shop floor where nano-OHS is addressed 1.3 Number of non-conformities with legal or internal standards in safety inspections 1.4 Non-conformities identified during inspections/audits 1.5 Number of solved safety non-conformances for the month 1.6 Percentage of corrective actions closed out within specified time-frame 1.7 Percentage of workers with adequate nano-OSH training; 1.8 Percentage of business partners (suppliers, contractors, etc.) evaluated and selected on the basis of their OSH performance or a widely accepted OSH certificate; 1.9 Frequency of (observed) (un)safe behaviour 1.10 Near-misses reported (that precede serious safety problems)	1.11 Number of accidents 1.12 Lost time (in hours) due to accidents 1.13 Health and safety prevention costs within the month 1.14 Cost of solved safety non-conformances for the month
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts	2.1.9 Number of inspections/audits to the shop floor where NMs and NPs consumption is addressed 2.1.10 Number of non-conformities with legal or internal standards in inspections 2.1.11 Non-conformities identified during inspections/audits 2.1.12 Percentage of corrective actions closed out within specified time-frame	2.1.1 Nanomaterials and nanoproducts consumption per period considered 2.1.2 Nanomaterials and nanoproducts intensity (consumed per unit of product manufactured) 2.1.3 Total nanomaterials and nanoproducts consumed by category 2.1.4 Nanomaterials and nanoproducts efficiency (ratio nano-wastes/NM-NP)

SD	SI	KPI	
		Leading KPI	**Lagging KPI**
		2.1.13 Percentage of workers with adequate NMs and NPs consumption training	2.1.5 Recycling/reuse intensity of nanomaterials and nanoproducts 2.1.6 Very hazardous nanomaterials and nanoproducts 2.1.7 Total cost of nanomaterials and nanoproducts management 2.1.8 Unit cost of nanomaterials and nanoproducts (per unit of product manufactured) 2.1.14 Number of emergency situations related to NMs and nanoproducts (spills, leaks, fire, explosion, etc)
	2.2 Nano-air emissions	2.2.7 Number of inspections/audits to the shop floor where nano-air emissions are addressed 2.2.8 Number of non-conformities with legal or internal standards in inspections 2.2.9 Non-conformities identified during inspections/audits 2.2.10 Percentage of corrective actions closed out within specified time-frame 2.2.11 Percentage of workers with adequate nano-air emissions training	2.2.1 Nano-air emissions generation per period considered 2.2.2 Nano-air emissions intensity (emissions generated per unit of product) 2.2.3 Total nano-air emissions by category of NMs 2.2.4 Nano-air emissions containing very hazardous NMs 2.2.5 Total cost of nano-air emissions management 2.2.6 Unit cost of nano-air emissions (per unit of product) 2.2.12 Number of emergency situations related to nano-air emissions
	2.3 Nano-wastewaters	2.3.11 Number of inspections/audits to the shop floor where nano-wastewaters are addressed 2.3.12 Number of non-conformities with legal or internal standards in inspections 2.3.13 Non-conformities identified during inspections/audits 2.3.14 Percentage of corrective actions closed out within specified time-frame	2.3.1 Total water consumption 2.3.2 Water intensity (consumption per unit of product manufactured) 2.3.3 Water efficiency (ratio nano-wastewater/raw water) 2.3.4 Nano-wastewaters generation per period considered

SD	SI	KPI	
		Leading KPI	**Lagging KPI**
		2.3.16 Percentage of workers with adequate nano-wastewaters training	2.3.5 Nano-wastewaters intensity (wastewaters discharged per unit of product) 2.3.6 Total nano-wastewaters by category of NMs 2.3.7 Treated nano-wastewaters 2.3.8 Nano-wastewaters containing very hazardous NMs 2.3.9 Total cost of nano-wastewaters management 2.3.10 Unit cost of nano-wastewaters (per unit of product) 2 2.3.17 Number of emergency situations related to nano-wastewaters (spills, leaks, etc)
	2.4 Nano-wastes	2.4.11 Number of inspections/audits to the shop floor where nano-wastes are addressed 2.4.12 Number of non-conformities with legal or internal standards in inspections 2.4.13 Non-conformities identified during inspections/audits 2.4.14 Percentage of corrective actions closed out within specified time-frame2 2.4.15 Percentage of workers with adequate nano-wastes training	2.4.1 Nano-wastes generation per period considered 2.4.2 Nano-wastes intensity (wastes generated per unit of product manufactured 2.4.3 Total nano-wastes by category of NMs 2.4.4 Nano-wastes recycled / reused in the process 2.4.5 Recycling/reuse intensity of nano-wastes 2.4.6 Nano-wastes managed with an accredited manager 2.4.7 Nano-wastes containing very hazardous NMs 2.4.8 Total cost of nano-wastes management 2.4.9 Cost of nano-wastes managed with an authorized manager 2.4.10 Unit cost of nano-wastes (per unit of product) 2.4.16 Number of emergency situations related to nano-wastes (spills, leaks, fire, explosion, etc)
	2.5 Energy	2.5.5 Number of inspections/audits to the shop floor where energy consumption is addressed	2.5.1 Energy consumption per period considered

SD	SI	KPI	
		Leading KPI	**Lagging KPI**
		2.5.6 Number of non-conformities with legal or internal standards in inspections 2.5.7 Non-conformities identified during inspections/audits 2.5.8 Percentage of corrective actions closed out within specified time-frame 2.5.9 Percentage of workers with adequate energy training	2.5.2 Energy intensity (energy consumption per unit of product manufactured 2.5.3 Energy consumption by source 2.5.4 Total cost of energy consumption
3. ECONOMY	3.1 Economic performance	3.1.5 Number of inspections/audits where energy is addressed 3.1.6 Non-conformities identified during inspections/audits 3.1.7 Percentage of corrective actions closed out within specified time-frame 3.1.8 Percentage of workers with adequate energy training	3.1.1 Annual turnover 3.1.2 Benefits 3.1.3 Unitary 3.1.4 Production capacity vs market demand margin
	3.2 Quality	3.2.5 Number of quality audits 3.2.6 Number of non-conformities with quality standards in inspections 3.2.7 Non-conformities identified during audits 3.2.8 Percentage of corrective actions closed out within specified time-frame 3.2.9 Percentage of workers with adequate quality training	3.2.1 Customer claims 3.2.2 Defective products 3.2.3 Non-quality costs / turnover 3.2.4 FTT (First Time Through)
	3.3 Digitalization	3.3.6 Number of digital inspections/audits 3.3.7 Number of non-conformities with digital standards in inspections/audits	3.3.1 IS/IT personnel 3.3.2 Investment in ICT equipment + software 3.3.3 Labour cost from the total manufacturing cost 3.3.4 Process steps with data digital transactions

SD	SI	KPI	
		Leading KPI	**Lagging KPI**
		3.3.8 Non-conformities identified during inspections/audits 3.3.9 Percentage of corrective actions closed out within specified time-frame 3.3.10 Percentage of workers with adequate digital training	3.3.5 Process steps with automatic process control (PLC or similar)

Table 14 shows a template for KPIs description according to ISO 22400-2:2014 [28]

Table 14 — Template for KPIs description according to ISO 22400-2:2014 [28]

KPI description	
Content:	
Name	Name of the KPI.
ID	A user defined unique identification of the KPI in the user environment.
Description	A brief description of the KPI.
Scope	Identification of the element that the KPI is relevant for, which can be a work unit, work centre or production order, product or personnel.
Formula	The mathematical formula of the KPI specified in terms of elements.
Unit of measure	The basic unit of dimension in which the KPI is expressed.
Range	Specifies the upper and lower logical limits of the KPI.
Trend	Is the information about the improvement direction, higher is better or lower is better.
Context:	
Timing	A KPI can be calculated either in: • Real-time – after each new data acquisition event. • On demand – after a specific data selection request. • Periodically – done at a certain interval, e.g. once per day.
Audience	Audience is the user group typically using this KPI. The user groups used in ISO 22400-2:2014 [28] are: • Operators – personnel responsible for the direct operation of the equipment. • Supervisors – personnel responsible for directing the activities of the operators. • Management – personnel responsible for the overall execution of production.
Production methodology	Specifies the production methodology that the KPI is generally applicable for: • Discrete. • Batch. • Continuous.
Effect model diagram	The effect model diagram is a graphical representation of the dependencies of the KPI elements that can be used to drill down and understand the source of the element values. NOTE This is a quick analysis which supports rapid efficiency improvement by corrective actions, and thus reduces errors.
Notes	Can contain additional information related to the KPI. Typical examples are: • Constraints. • Usage. • Other information.

Table 15 shows an example of the registration and calculation procedure with KPIs to build the Current and Target baselines for Sustainability Results.

Table 15 — Record to collect data on KPIs to build the baselines (Current and Target) of Sustainability Results. The record includes two KPIs as an example

Sustainability Dimension (SD)	Sustainability Item (SI)	Current Baseline/Target Baseline								
		KPI				Current Baseline		Target Baseline		
		Name	Trend	Unit	Period	KPIc value	sKPIc	Improvement (%)	KPIt value	sKPIt
1. SOCIAL	1.1 Nano-OHS									
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts									
	2.2 Nano-air emissions									
	2.3 Nano-wastewaters									
	2.4 Nano-wastes	KPI3 - Liquid-wastes containing CNTs traces (intensity)	-	l/kg	Monthly, annually	300	100	20	240	80
	2.5 Energy									
3. ECONOMY	3.1 Economic performance	KPI4 Buckypapers production	+	m^2/week	Weekly, monthly, annually	5	10	900	50	100
	3.2 Quality									
	3.3 Digitization									

Trend: Negative trend (-) The lower the better (e.g. energy, NMs, nano-air emissions, nano-wastes, nano-wastewaters, etc); Positive trend (+) The higher the better (e.g. production, sales, people trained, digitalization, etc)

KPIc = current KPIs;

sKPIc= standardized current KPI;

KPIt = target KPIs;

sKPIt= standardized target KPI;

4.5 Sustainability dashboard

The SNF model shows its two pillars (Sustainability Management - SM and Sustainability Results - SR) and the Sustainability Nanomanufacturing Index (SNFI), using a dashboard.

This dashboard (Figure 1) allows monitoring the progress of sustainability in the NPL, by displaying the current and target baselines for the areas of management (SM) and results (SR) through two radar diagrams, for the period considered, In addition, the dashboard also displays the current and target values of the Nanofabrication Sustainability Index (SNFI) through a bar graph.

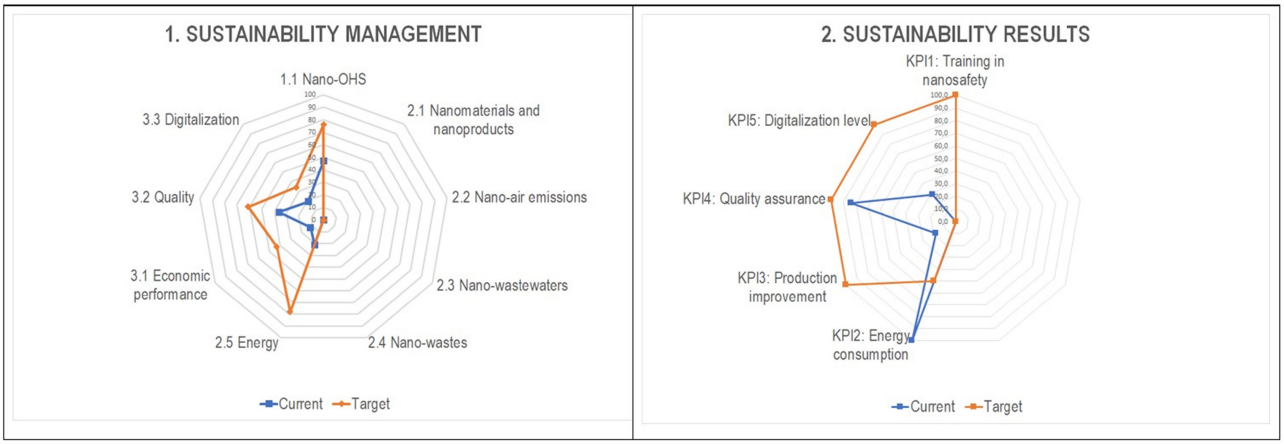

Figure 1 — Sustainability Dashboard showing, through radar diagrams, the baselines (Current and Target) for the two pillars of the SNF: 1) Sustainability Management (SM) and 2) Sustainability Results (SR)

Regarding the baselines of the SR pillar, the absolute values of KPIs can be shown in the radar diagram using different scales. Another alternative is to convert all the KPIs to a percentage scale. This last solution has been used in the first version of the Excel OASIS-SNF Tool. The calculation rule used is shown in Table 16 below.

Table 16 — Calculation rule for the absolute values of the KPIs in a percentage scale

KPI trend	Upper limit of the diagram	Lower limit of the diagram
-	100	KPIt*100/KPIc
+	KPIc*100/KPIt	100

NOTE In case that, due to the specificities of the NPL, radar diagrams are not clear enough, histograms can be used.

4.6 Sustainability improvement plan

The Improvement Plan shows those activities defined by the NPL to implement the sustainability objectives established in each SD and SI, as well as the corresponding KPIs to monitor the progress and fulfilment of each objective.

In addition, for each activity, the start and end dates, the status, the resources to be implemented and the person responsible for the implementation of the activity are recorded, see Table 17.

Table 17 — Template for the Sustainability Improvement plan

SD	SI	Objective	KPI	Activity	Start date	End date	Status	Resources	Responsible
1. SOCIAL	1.1 Nano-OHS	1							
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts	2							
	2.3 Nano-wastewaters	3							
		4							
	2.4 Nano-wastes	5							
	2.5 Energy	6							
3. ECONOMIC	3.1 Economic performance	7							
	3.2 Quality	8							
	3.3 Digitalization	9							

5 Operating procedure to evaluate the SNF and to build the sustainability dashboard

The operational procedure to assess the SNF and build the sustainability dashboard can be summarized in 10 steps, as follows (see Figure 2):

Step 1. Diagnosis customization. The basic data of the NPL and the contact persons are registered (Basic information). In addition, the evaluator customizes the diagnosis by selecting those SDs and SIs considered as significant by the NPL. The sustainability improvement will be focused on those areas. This selection can be made according to the evaluator's criteria, taking into account the evidence from the information provided by the NPL. If more solid decision support is required, decision tools such as tools for assessing the significance of environmental aspects, or multi-criteria matrices, can be used. names of the SIs can also be customized according to the criteria of the NPL (e.g., the NPL could name SI "2.4 Nano-wastes" as "2.4 Liquid waste management containing MWCNTs", because this denomination is closer to its activity).

Sustainability Management assessment

Step 2. Scoring the SM-questionnaires. For the evaluation of SDs and SIs, the three questionnaires respectively called SD1. Social, SD2. Environment and SD3. Economy (Tables 2 to 10) are used. In these questionnaires, each SI is evaluated using 10 questions. The evaluator scores each question between 0 and 10, according to his/her professional criteria, based on the evidence of the information provided by the NPL. A guiding criteria for scoring questions could be: No management (0), Basic management (1-4), Advanced management (5-7), Documented management (8-9), Continuous improvement in management (10)].

Step 3. Calculating the SM Current Baseline. The scores by SI [Total Item Score (TSIS)], by SD [Total Dimension Score (TSDS)] and finally, the OASIS-SNF Index (OASIS-SNFI) that summarizes in a single parameter the results of the diagnosis, are calculated using the sustainability management calculations described in section 4.3.2 and the punctuations showed in Table 11. All values are percentages and therefore intuitively interpretable on a 0-100 scale. A current baseline SM can then be defined with the values of the corresponding SIs.

Step 4. Calculating the SM Target Baseline. In the same way as described in step 3, you can proceed to calculate the baseline target with the improvement values proposed in the questionnaires.

Step 5. Visualizing the SM-baselines through the dashboard (SM - radar diagram). The results of the current (blue) and target (orange) baselines can be plotted on a radar diagram, to intuitively show the initial situation and the future situation of the proposed improvement.

Sustainability Results assessment

Step 6. Defining KPIs and calculating the SR-current baseline. The NPL needs to define a set of KPIs to monitor the improvement in the selected SIs. Table 15 is used to select and parametrize KPIs. To facilitate the selection of KPIs, Table 13 provides a non-exhaustive list of KPIs that can be used to monitor SIs. Some KPIs are probably already used by the NPL, although others will be new. It is very important to select KPIs whose data are easy to collect (feasibility) and which are also easy to calculate with the available data (simplicity). At least one KPI must be defined for each SI selected. The values of the KPIs can be normalized to percentages (%) to be easily visualized in a radar diagram.

Step 7. Calculating the SR-target baseline. In the same way as described in step 6, the baseline target is calculated using the improvement values proposed for the KPIs.

Step 8. Visualizing the SR-baselines through the dashboard (SR - radar diagram). Once the values of the KPIs have been entered in tab 15, the results of the current (blue) and target (orange) SR-baselines

can be plotted on a radar diagram, to intuitively show the initial situation and the future situation of the proposed improvement. Recommendations on the construction of the SR-radar diagram can be found in section 4.5.

Step 9. Improvement Plan. Table 17 provides a template for preparing the Improvement Plan. One or more improvement objectives are defined for each of the significant SIs. A KPI and a set of activities for its deployment are defined for each objective. The start date, the expected end date, the status (the Improvement Plan is a dynamic document), the resources to be considered for its deployment and the responsible person for carrying out the activity, are recorded for each activity. The template is customized according to the NPL needs (number of objectives, number of activities, etc).

Step 10. Reporting and acceptation. A short report compiling the results of the Diagnosis and the Improvement Plan are delivered to the representatives of the NPL, for its consensus and acceptance. The results should be presented in a meeting with the representatives of the NPL. The acceptance of the above document by the representatives of the NPL is recorded on the document (signature).

Figure 2 shows the 10 steps operational procedure to be followed by the evaluator to develop the diagnosis of a NPL with respect to the SNF.

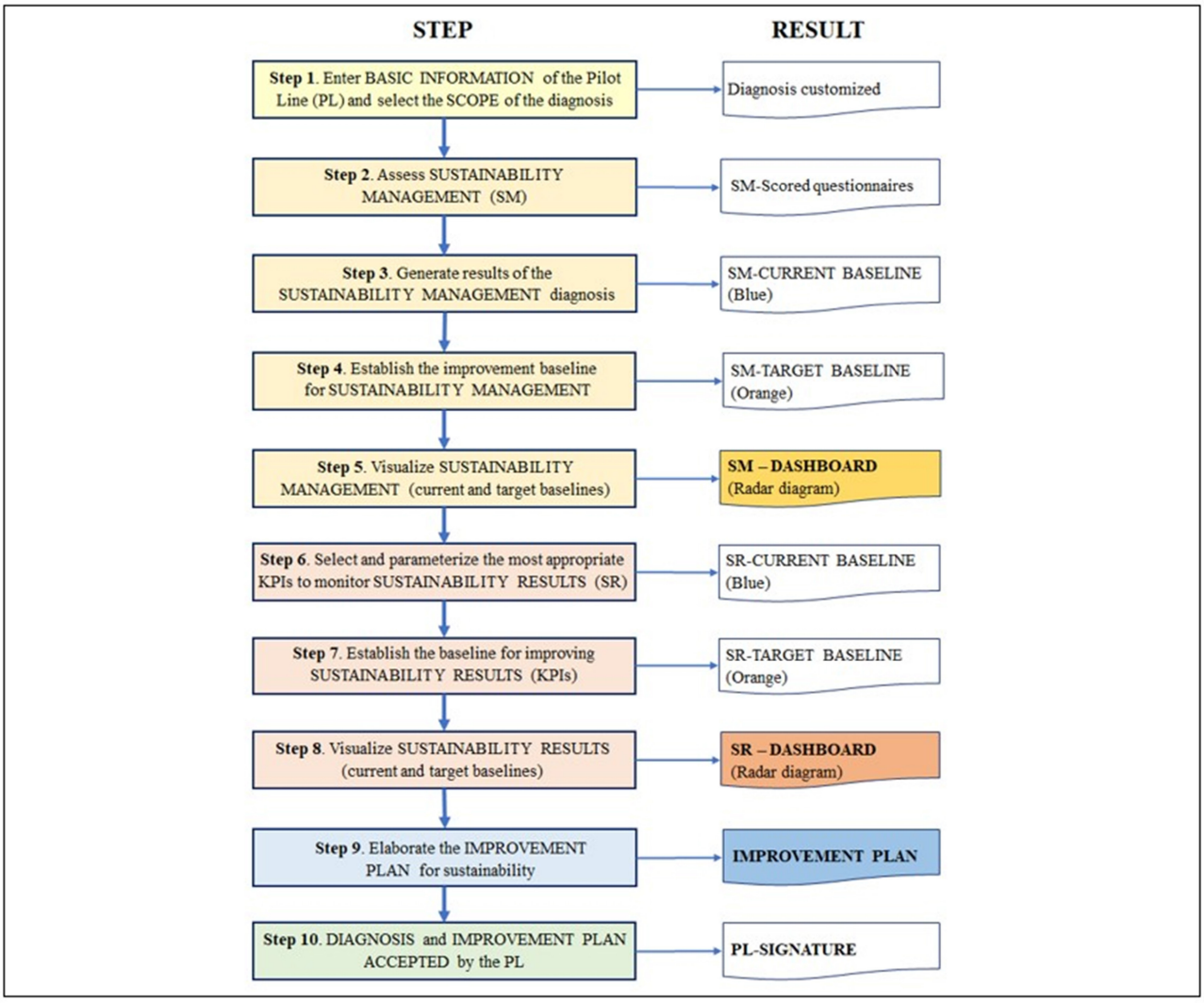

Figure 2 — 10-step procedure to develop the diagnosis of the model using the SNF Tool

6 SNF implementation and continuous improvement

6.1 Plan-Do-Check-Act cycle and SNF deployment

The deployment of the SNF in the NPLs during the successive stages of the innovation process (TRLs), is founded on the concept of PDCA (Plan-Do-Check-Act) cycle of continuous improvement (see Figure 3).

The PDCA concept is an iterative process used by organizations to achieve continual improvement. It can be applied to all processes. The PDCA cycle of the SNF can be described in short as follows:

1) Plan (P): determine and assess sustainability priorities, establish sustainability objectives connected with sustainability priorities, establish KPIs to monitor such priorities and necessary actions to deliver sustainability results

2) Do (D): implement what was planned (Improvement Plan),

3) Check (C): monitor and measure activities and processes with regard to the sustainability management and sustainability results, and report the results,

4) Act (A): take actions to continually improve the nano-sustainability performance to achieve the intended outcomes (updating the Improvement Plan).

In this first version of the document, the results on the implementation of the SNF in the NPLs encapsulated in Annexes A, B and C, only refer to stages 0 (D-Diagnosis) and 1 (P-Planning) of the PDCA cycle.

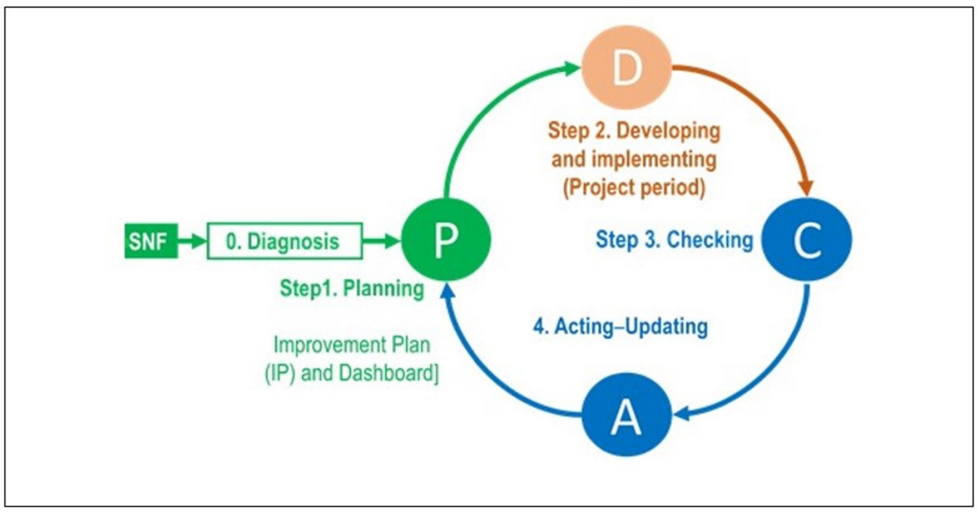

Figure 3 — Deployment of the SNF through a PDCA cycle of continuous improvement

6.2 SNF deployment

The main activities and resources to consider in the deployment of the SNF in a NPL are the following:

Step 0. Diagnosis (D) and Step 1. Planning (P)

Activities at these stages (0/1) should be carried out in parallel:

- Mapping of the processes and impacts of the NPL (Flow charts).
- Identification of regulatory and other requirements (customized for the NPL). Eight regulatory fields have been proposed to encapsulate regulatory requirements (RR), one per SI, and four regulatory levels: 1) European, 2) National, 3) Regional and 4) Local).
- Identification of sustainability priorities (SDs and SIs).
- Based on the questionnaires, evaluation of the starting point in sustainability management (Sustainability Management Current Baseline)
- Establishment of a management improvement baseline (Sustainability Management Target Baseline)
- Selection of KPIs for monitoring Sustainability Results
- Based on KPIs selected by the NPL, evaluation of the starting point in sustainability results (Sustainability Results Current Baseline)
- Establishment of a results improvement baseline (Sustainability Results Target Baseline)
- Dashboard generation: two radar diagrams, showing current and target baselines for Sustainability Management and Sustainability Results, and a bar graph for the SNFI.
- Improvement Plan (IP) elaboration, based on the results of the diagnosis and including all actions to be deployed to improve nano-sustainability.

Step 2. Developing/Implementing (D)

Activities at this stage should focus on:

- Training of the representatives of the NPL on the SNF, using the diagnostic results and the improvement plan as an example.
- Implementation of the improvement plan by the representatives of the NPL.
- Monitoring by the representatives of the NPL of the progress in the implementation of the SNF (Dashboard).

Step 3. Checking (C) and Step 4. Acting/Updating (A)

Activities at these stages (3/4) should be carried out in parallel:

- Internal checking by the representatives of the NPL prior to the external checking.
- External checking:
  - Implementation of the Improvement Plan for nano-sustainability
  - Dashboard (Sustainability management and Sustainability results)
- EHS measurement campaign, if necessary
- Updating the improvement plan and the dashboard (Management and Results, and SNFI).

Annex A
(informative)

Practical example of the implementation of the operating procedure to assess the SNF and build the sustainability dashboard, in Nanomanufacturing Pilot Line 4 (NPL 4) of the OASIS project (EU-project OASIS – GA 814581)

A.1 Introduction

This Annex A shows, through an example based on NPL4, the practical application of the 10-step SNF evaluation procedure (see Figure A.1) described in section 5 of this document.

The OASIS project has developed a simple software based on MS Excel (OASIS-SNF Tool) to automate this procedure. This tool has been used by the project to diagnose, implement, monitor and re-evaluate management practices and sustainability results in NPLs, in conformity with the requirements of the SNF model.

It is envisaged that a new version of the OASIS-SNF Tool will be publicly available at the website of OASIS (https://project-oasis.eu/) at the end of the project (November 2022).

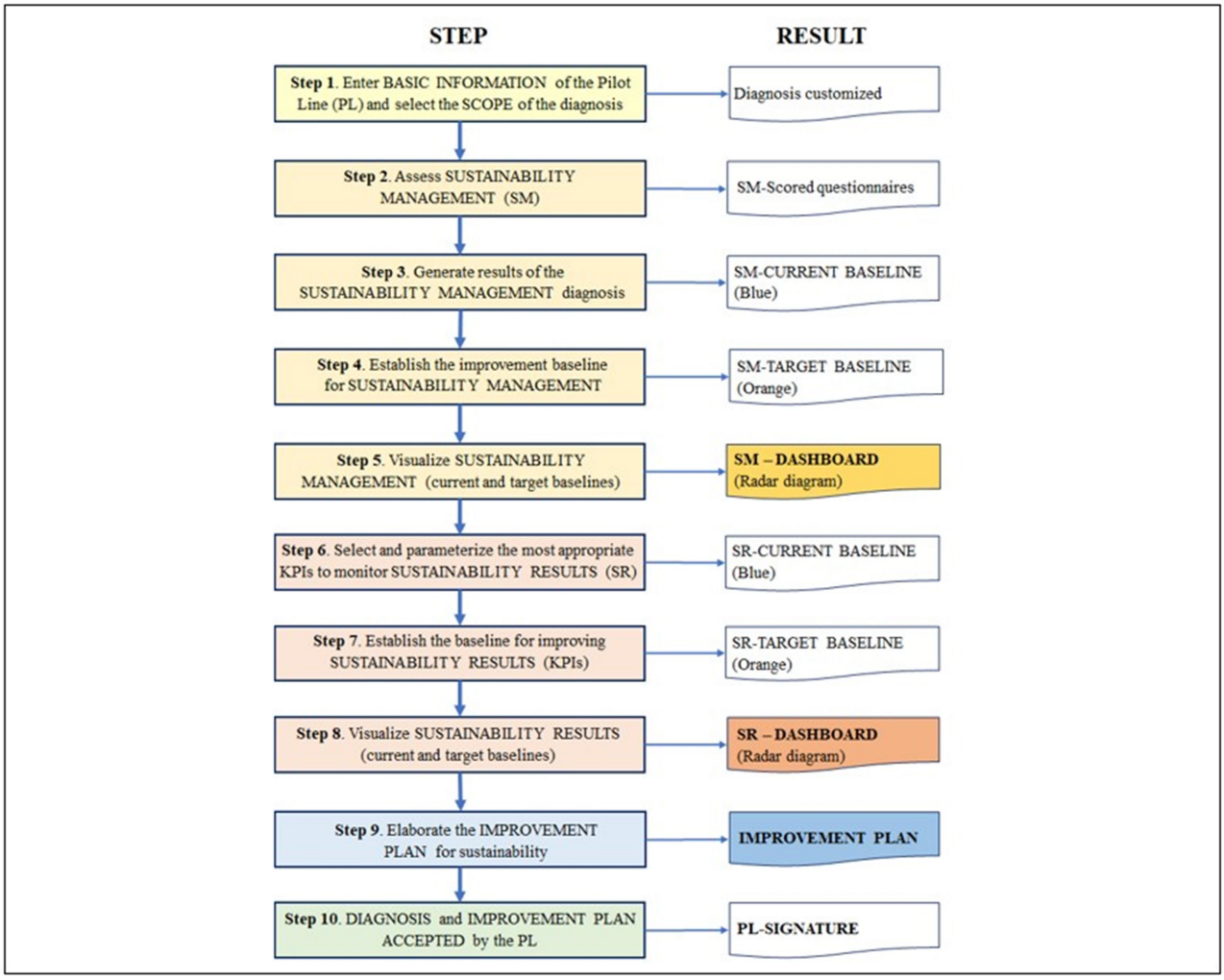

Figure A.1 — 10-step SNF evaluation procedure

A.2 SNF customization

Step 1. Diagnosis customization. The diagnosis of NPL4 has been customized by selecting those SDs and SIs considered as priorities by the NPL. The scope diagnosis has been agreed with the NPL, taking into account the information provided by the NPL, the needs raised in the field of sustainability, the requirements of the project OASIS, and finally, the criteria of the evaluator. Table A.1 shows the scope finally established, and the SDs and SIs selected by the NPL where it wants to focus the improvement of sustainability.

Table A.1 — Scope for the diagnosis agreed with NPL4

Scope			
SD	**SI**	**Yes**	**No**
1 SOCIAL	1.1 Nano-OHS	X	
2. ENVIRONMENT	2.1 Nanomaterials and nanoproducts	X	
	2.2 Nano air emissions		X
	2.3 Nano wastewaters		X
	2.4 Nano-Wastes	X	

	2.5 Energy		X
3. ECONOMY	3.1 Economic performance	X	
	3.2 Quality	X	
	3.3 Digitization	X	

As can be noted, three SIs were removed from the scope: Nano air emissions, Nano wastewaters and Energy. This makes it necessary to readjust the weights initially established by the model for the SIs in Table 11. The new weights, that will be used by the model to calculate the SM-baselines, can be seen in Tables A.3 and A.4, column called "SI Weighting (SIW)".

A.3 Sustainability Management assessment (SM)

Step 2. Scoring the SM-questionnaires. For the evaluation of SDs/SIs, the corresponding questionnaires (Tables 2 to 10 of the CWA) were used. However, questionnaires 2.2, 2.3 and 2.5 of SD2 (Tables 4, 5 and 7 of the document) were removed since these SIs were excluded from the scope of the diagnosis in NPL4.

The evaluator scored each question between 0 and 10, according to his/her professional criteria, based on the evidence of the information provided by the NPL.

First, the evaluator scored the questions by analysing the current situation (Current score column); then, he scored the same questions again, but this time thinking about the improved situation that can be expected at the end of the period considered (Target score column). The difference between both scores, target and current, is the improvement rate.

The evaluator also recorded in the questionnaires those sustainability management measures/practices related to the questions and already implemented in NPL4. Similarly, he also registered those other management measures/practices, not yet implemented in the NPL, and which, in his/her opinion, could be implemented to improve sustainability.

The total scores of the SIs evaluated are transferred respectively to Table A.3 (Current) and Table A.4 (target) for subsequent calculations (TSIS columns).

As an example, Table A.2 encapsulates a questionnaire ["Nano-OHS" (SI 1.1)], filled in for NPL4.

Step 3. Calculating the SM Current Baseline. Using current scores obtained for the SIs in Step 2 and the calculation procedure established in Table A.3, the scores by SI [Total Item Score (TSIS)], by SD [Total Dimension Score (TSDS)] and finally, the OASIS-SNF Index (OASIS-SNFI) that summarizes in a single parameter the results of the diagnosis, were calculated for NPL4. All values are percentage. Then, a current SM-baseline (Blue line) was defined for NPL4, with the values of the corresponding SIs (Table C.3, column TSIS).

Step 4. Calculating the SM Target Baseline. Similarly, as described in step 3, we proceeded with the target scores obtained for the SIs in step 2 and calculated in Table C.4 the corresponding values for TSIS, TSDS and SNFI. Then, a target SM-baseline (Orange line) for NPL4 was defined with the values of the corresponding SIs (Table A.4, column TSIS).

Step 5. Visualizing the SM-baselines through the dashboard and the SNFI. The values of the TSIS columns in Tables A.3 and A.4, that contain respectively the current and target scores of the evaluated SIs, were plotted on a radar diagram, to intuitively show the initial situation (Blue baseline) and the future situation (Orange baseline) of the proposed improvement. Figure A.2.1 shows this diagram for NPL4.

In addition, the current and target values calculated respectively for the SNFI in Tables A.3 and A.4, were also plotted using a histogram to visualize their evolution. Figure A.3 shows this plot for NPL4.

A.4 Sustainability Results assessment (SR)

Step 6. Defining KPIs and calculating the SR-current baseline.

Table A.5 encapsulates the 7 KPIs selected by NPL4 to monitor its priority aspects of sustainability. Two KPIs (KPI1 and KPI6) do not have an established starting value (Current). KPIc values were standardized to percentages (%) to be easily visualized in a radar diagram (sKPIc). Then, the current SR-baseline for NPL4 (blue baseline) was constructed using the values displayed in column sKIPc of Table A.5.

Step 7. Calculating the SR-target baseline. The target KPIs in Table C.5 were estimated, either directly or by multiplying the current values (KPIc) by an improvement percentage. Similarly, as described in step 6, we proceeded to calculate the SR - target baseline (Orange baseline) for NPL4, using the standardized values displayed in column sKPIt of Table A.5.

Step 8. Visualizing the SR-baselines through the dashboard (SR - radar diagram).

The SR-baselines, current (Blue) and target (Orange), built with the standardized KPI values (sKPIc and SKPIt respectively, Table A.4), were plotted on a radar diagram, to intuitively show the initial situation and the future situation of the proposed improvement. Figure A.2.2 shows this diagram for NPL4.

A.5 Sustainability improvement

Step 9. Improvement Plan. Table A.6 shows the Improvement Plan developed by NPL4 to improve its sustainability priorities during the project period. For each SI priority, one or more improvement objectives were defined, a total of 7. Each objective was associated with a KPI to monitor its evolution. A set of activities was defined to deploy each objective. For each of the activities, the starting date, the expected completion date, the status, the resources to be considered for deployment during the project, as well as the person responsible for carrying out the activity, were defined.

Step 10. Reporting and acceptation. Finally, a short report compiling the results of the Diagnosis and the Improvement Plan were prepared for NPL4. The acceptance by the NPL4 of the above document was recorded on the document (signature).

Table A.2 — Sustainability Management assessment. Example of the questionnaire filled in NPL4 to evaluate the SI "Nano-OHS" (SI 1.1), within the SOCIAL SD (SD1)

SD1.- Social								
SI	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Improvement rate**
1.1 nano OHS	1.1.1	Basic managerial practices about the risks to the safety and health of workers derived of the use/handling of nanomaterials and nanoproducts (OHS nanorisks, such as e.g. explosion, fire, exposure by inhalation, etc) have been identified.	Yes	10,0	Integrated management system certified (Quality EN ISO 9001 [2]: 2015; Environment EN ISO 14001: 2015 [3] and R&D UNE 166002: 2014) [42]. OHSMS implemented (non-certified), in accordance with the Spanish Labour Risk Prevention Law (transposition of the Directive 89/391 / EEC).	See Improvement Plan	10	0,0
	1.1.2	Hot spots connected with OHS-nanorisks have been identified	Yes	10,0	Risk assessment (RA) developed by H2020 project PLATFORM.	See Improvement Plan	10	0,0
	1.1.3	Regulatory requirements on OHS-nanorisks have been identified and are known	Yes	6,0	Not well known, not documented.	See Improvement Plan	8	2,0
	1.1.4	OHS-nanorisks have been evaluated, including potential emergency situations.	Yes	7,0	Risk assessment developed by H2020 project PLATFORM. Not systematic.	See Improvement Plan	8	1,0

SD1.- Social								
SI	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Improvement rate**
		Risk assessment is permanently updated with the evolution of working conditions and new technologies.						
	1.1.5	Specific preventive and protective measures against nanorisks have been implemented according to risk assessment and following the hierarchical STOP approach (Substitution, Technological, Organizational and PPEs), and are properly maintained and periodically reviewed to ensure maximum effectiveness.	Yes	7,0	Main preventive and protective measures against nanorisks have been implemented according to PLATFORM-RA and following STOP principles. Some measures remain still pending (e.g. dedicated room).	See Improvement Plan	8	1,0
	1.1.6	In particular, PPEs (clothing, masks, gloves, etc) have been appropriately selected, supplied to workers,	Yes	7,0	According to materials Safety Data Sheets (SDSs) and PLATFORM-RA.	See Improvement Plan	7	0,0

SD1.- Social								
SI	**Question**		**Current Baseline**			**Target Baseline**		
			Fully or partially implemented? Yes/No	**Current score**	**Practices already implemented**	**Practices to be implemented to reach the target baseline**	**Target score**	**Improvement rate**
		used and properly maintained.						
	1.1.7	Workers have been consulted, informed and appropriately trained about nanorisks.	Yes	5,0	General training done.	See Improvement Plan	10	5,0
	1.1.8	Information on the OHS risks of used/handled nanomaterials and nanoproducts is available through the corresponding Safety Data Sheets (SDS)	Yes	7,0	CNTs-Nanocyl SDS, Buckypaper - TECNALIA SDS	See Improvement Plan	10	3,0
	1.1.9	A systematic management of OHS-nanorisks has been deployed (objectives, organization, documentation)	Yes	6,0	TECNALIA-OHSMS implemented (non-certified), in accordance with the Spanish Labour Risk Prevention Law (transposition of the Directive 89/391 / EEC).	See Improvement Plan	6	0,0
	1.1.10	Improvement objectives for the management of OHS-nanorisks have been established.	No	0,0		See Improvement Plan	9	9,0
	TOTAL			**65,0**			**86**	**21**

Table A.3 — Sustainability Management assessment. Internal calculations of the SNF model to compute the value of the SIs, SDs and finally the SNFI for the Current SM baseline. This table also shows the new parameterization of the model according to the SIs selected by NPL4 [compare the new weights (SIWs) with the values shown in Table 11 of the document]

Sustainability Dimension (SD)	Sustainability Item (SI)	SM – CURRENT BASELINE							
		Number of questions to be Answered (NQA)	Score by question (SBQ)	Total SI Score (TSIS)	SI Weighting (SIW)	Total SI Score Weighted (TSISW)	Total SD Score (TSDS)	SD Weighting (SDW)	Sustainable Nano-manufacturing Index (SNFI)
1. SOCIAL	1.1 Nano-OHS	10	10	**65**	1,00	65,0	**65,0**	0,33	**21,5**
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts	10	10	**53**	0,50	26,5	**58,5**	0,33	**19,3**
	2.2 Nano-air emissions								
	2.3 Nano-wastewaters								
	2.4 Nano-wastes	10	10	**64**	0,50	32,0			
	2.5 Energy								
3. ECONOMIC	3.1 Economic performance	10	10	**34**	0,34	11,6	**12,2**	0,34	**12,2**
	3.2 Quality	10	10	**50**	0,33	16,5			
	3.3 Digitization	10	10	**24**	0,33	7,9			
Total		60	600	**290**	3,00	300,0	**36,0**	1,00	**53,0**

Table A.4 — Sustainability Management assessment. Internal calculations of the SNF model to compute the value of the SIs, SDs and finally the SNFI for the Target SM baseline

Sustainability Dimension (SD)	Sustainability Item (SI)	SM – TARGET BASELINE							
		Number of questions to be Answered (NQA)	Score by question (SBQ)	Total SI Score (TSIS)	SI Weighting (SIW)	Total SI Score Weighted (TSISW)	Total SD Score (TSDS)	SD Weighting (SDW)	Sustainable Nano-manufacturing Index (SNFI)
1. SOCIAL	1.1 Nano-OHS	10	10	**86**	1,00	86	**86**	0,33	**28,4**
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts	10	10	84	0,50	42	**85,5**	0,33	**28,2**
	2.2 Nano-air emissions								
	2.3 Nano-wastewaters								
	2.4 Nano-wastes	10	10	**87**	0,50	43,5			
	2.5 Energy								
3. ECONOMIC	3.1 Economic performance	10	10	**72**	0,34	24,5	**57,8**	0,34	**19,7**
	3.2 Quality	10	10	**73**	0,33	24,1			
	3.3 Digitization	10	10	**28**	0,33	9,2			
Total		60	600	**430**	3,00	300	**229,3**	1	**76,3**

Table A.5 — Sustainability Results assessment. Internal calculations of the SNF model to compute KPIs to build the Current and Target SR baselines

SD	SI	KPI				SR - Current Baseline		SR - Target Baseline		
		Name	Trend	Unit	Period	KPIc value	sKPIc	Improvement (%)	KPIt value	sKPIt
1. SOCIAL	1.1 Nano-OHS	KPI1 Observed unsafe behaviours/work conditions (nanorisks)	-	Number	M, A	0 (*)	100	NIV	2	50
2. ENVIRONMENTAL	2.1 Nanomaterials and nanoproducts	KPI2 CNT concentrate consumption intensity	-	kg/kg	M, A	42	100	5	40	95
	2.2 Nano-air emissions									
	2.3 Nano-wastewaters									
	2.4 Nano-wastes	KPI3 - Liquid-wastes containing CNTs traces (intensity)	-	l/kg	M, A	300	100	20	240	80
	2.5 Energy									
3. ECONOMY	3.1 Economic performance	KPI4 Buckypapers production	+	m^2/week	W, M, A	5	10	900	50	100
		KPI5 Annual turnover	+	k€	A	1	20	20	5	100
	3.2 Quality	KPI6 Quality assurance	-	Defects/m^2	M, A	0 (*)	100	NIV	2	50
	3.3 Digitization	KPI7 Level of digitalization	+	%	A	24	85,7	20	28	100

KPIc = current KPI;
sKPIc = calculated value of the KPIc for its representation in a percentage axis;
KPIt = target KPI;
sKPIt = idem sKPIc, but for the KPIt;
NIV = KPI without initial value [(0)*];
Period: A (Annually, M (Monthly), W (Weekly)

Table A.6 — Improvement Plan developed by NPL4 to improve its sustainability priorities during the project period

OASIS - SNF/IMPROVEMENT PLAN										
NPL		**PL4 Buckypapers**								
SD	**SI**	**Objective**	**KPI**		**Activity**	**Start date**	**End date**	**Status**	**Resources**	**Responsible**
1. Social	1.1 Nano-OHS	Reduce observed safety deviations with nanorisks (NIV)	KPI1. Observed unsafe behaviours/work conditions (nanorisks)	1	Adapt TECNALIA´s safety inspections (OHSMS) to PL4 and carry them out monthly.	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				2	Compile and analyse regulatory requirements	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				3	Implementation of monitoring with KPI1	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
2. Environment	2.1 NMs and NEPs	Reduce consumption of CNTs by 5 %	KPI2. CNT concentrate (MB) consumption intensity (kg/kg)	1	The same activity as 2.4.1	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Substitution of part of the CNT content with additional materials	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				3	Update Buckypaper SDS	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				4	Implementation of KPI2 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
	2.4 Nano-wastes	Reduce liquid-wastes containing CNTs by 20 %	KPI3. Liquid-wastes containing CNTs traces (l/kg)	1	Develop and implement a system to recycle filtered waters and minimize waste production	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Implementation of KPI3 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
3. Economic	3.1 Economic performance	Increase production by 10	KPI4 Buckypapers production (m2/week)	1	PL4 - upgrading and scaling activities, by integrating the modules and devices specified in T1.3 (WP1)	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				2	Implementation of KPI4 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner

OASIS - SNF/IMPROVEMENT PLAN										
NPL		PL4 Buckypapers								
SD	SI	Objective	KPI		Activity	Start date	End date	Status	Resources	Responsible
		Increase sales by 20 %	KPI5 Annual turnover (k€)	1	Increase the number of commercial visits among potential clients	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Study new industrial fields of application for the product	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				3	Increase added value of buckypaper (polymeric/metallic layers)	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				4	Strengthen product dissemination actions	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				5	Implementation of KPI5 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
	3.2 Quality	Reduce quality defects (No initial KPI value)	KPI6 Defective products (Number)	1	Implement a procedure for product quality defects monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				2	Implement an analytical methodology for the characterization of input materials (CNTs, surfactant)	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				3	Implementation of KPI6 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
	3.3 Digitalisation	Increase digitalisation level by 20 %	KPI7 Level of digitalization (%)	1	Implement a digital system to monitor and control key process parameters	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Implement a digital system to monitor and control dispersion preparation	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				3	Implementation of KPI7 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner

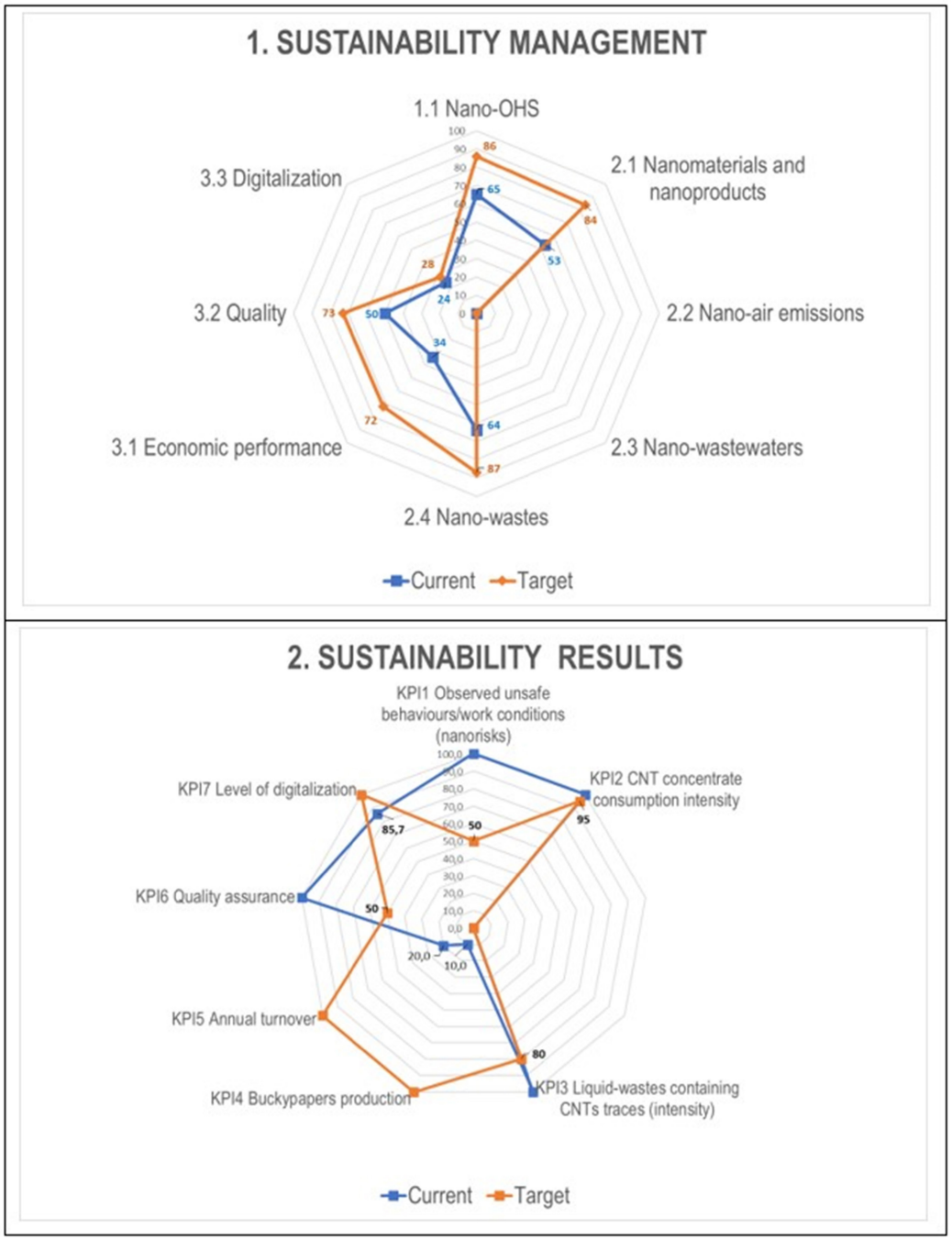

Figure A.2 — NPL4 dashboard. Radar diagram showing the current and target baselines for Sustainability Management (A.2.1, above) and Sustainability Results assessment (A.2.2, below)

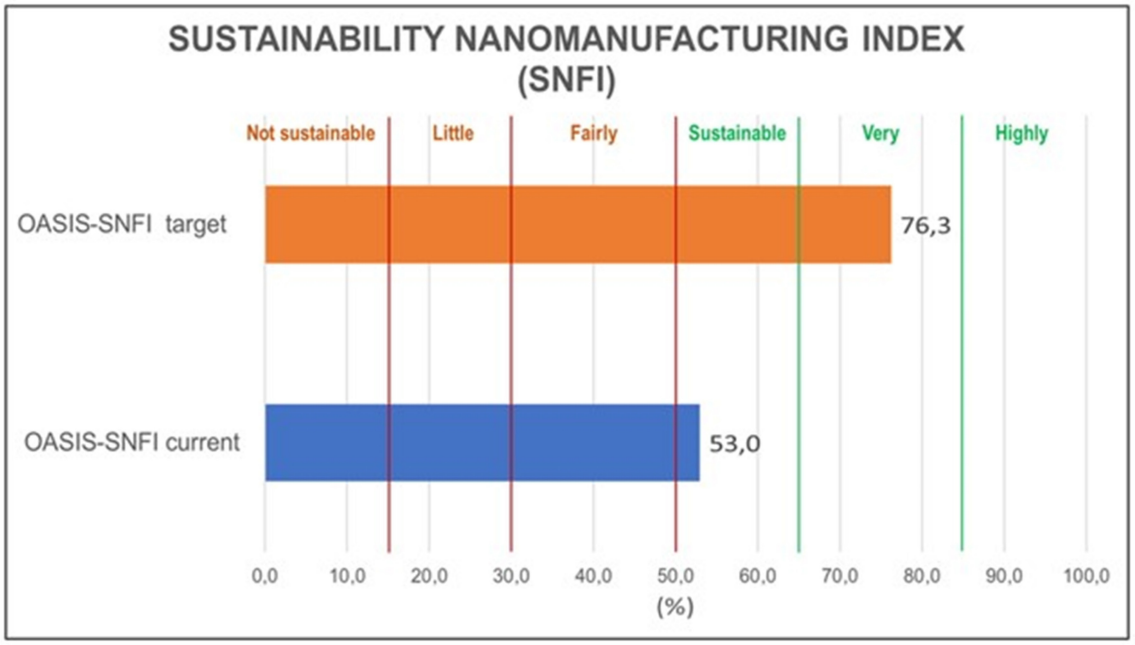

Figure A.3 — NPL4 dashboard. Bar chart showing current and target values of the SNFI

Annex B

(informative)

Use Cases of diagnosis (step 0) and planning (step 1) of Nanomanufacturing Pilot Lines of the OASIS project (EU-project OASIS – GA 814581)

B.1 Introduction

The pilot production ecosystem deployed by the EU-project OASIS (GA Nº 814581) consists of 12 Nanomanufacturing Pilot Lines (NPLs) for the manufacture of nanomaterials, nano-intermediates and nano-enabled products, intended for the final production of lightweight multifunctional products based on aluminium and polymer composites, for construction, energy, automotive and aeronautics.

OASIS intends to deploy this nanomanufacturing ecosystem under a common umbrella of sustainable production, to ensure a future competitive, quality, safe and environmentally friendly production of nanoproducts, in compliance with the applicable regulation.

In this context, this Annex B shows four use cases of the OASIS project where NPLs used the SNF for the initial diagnosis of the sustainability of their processes and to draft their improvement plans.

B.2 Use Case 1: Diagnosis (Step 0) and Planning (Step 1) performed in a Nanomanufacturing Pilot Line dedicated to aerogel materials

B.2.1 General

As a practical use case, Table B.1, Figure B.1, Figure B.3 and Table B.2 summarize the results of the diagnosis performed with the SNF in the OASIS NPL1, dedicated to the manufacture of aerogel materials.

B.2.2 NPL1 in brief

In short, NPL1 is a TRL4 semi-industrial Freeze Dryer that permits to obtain aerogel materials with exceptional properties such as: ultra- light density, high porosity, and low thermal conductivity. The porous material is firstly frozen and consequently sublimated under vacuum by a primary and secondary drying process. The NPL is a compact unit with casters, constructed in a steel stove-enamelled cabinet. It is equipped with a vial stoppering and spacing device, isolation valve chamber to condenser, micro suite software and a vacuum pump with exhaust filter. To fully understand the physicochemical properties of the final product is possible to monitor the experimental conditions. Also, this opportunity allows to control and improve the energy consumption during the freeze-drying process.

B.2.3 SNF customization and results

NPL1 customized the diagnosis of the SNF model, selecting the 3 SDs and five of the nine SIs (“materials”, “air emissions”, “wastewaters” and “wastes” were not selected as priorities at this time).

Regarding **Sustainability Management** in NPL1,

The compliance percentages for the three sustainability dimensions are respectively, 47.0 % for the Social Dimension, 21.0 % for the Environmental Dimension and 22.3 % for the Economic Dimension. The improvement percentages, estimated by NPL1 at the end of the OASIS project for the three sustainability dimensions, are respectively 29%, 57% and 23.7 %.

Five KPIs have been established by NPL1 to monitor **Sustainability Results**: KPI1: Training in nanosafety (number), KPI2: Energy consumption (kW·h), KPI3: Production improvement (m2/batch), KPI4: Quality

assurance (%) and KPI5: Digitalization level (%). One KPI has no initial value (KPI1). Since the KPIs monitoring system is not yet implemented in NPL1, the Sustainability Results have not been evaluated in this diagnosis. The improvement ratios expected by the KPIs at the end of the project range from 19 to 455 %.

The calculated OASIS-SNFI is 30; with an improvement rate of 36.4 %, to reach a score at the end of the project of 66.4.

A suitable and feasible **Sustainability Improvement Plan** including 24 actions has been elaborated by NPL1 to achieve planned sustainability goals in the areas of Sustainability Management and Sustainability Results, and a Dashboard to monitor progress in both fields has also been established (see Figure B.1 and Figure B.2).

Table B.1 — SNF implementation in OASIS-NPL1: scope of the diagnosis

Dimension	Item	Yes	No
1 Social	1.1 OHS	x	
2. Environment	2.1 Materials		x
	2.2 Air emissions		x
	2.3 Wastewaters		x
	2.4 Wastes		x
	2.5 Energy	x	
3. Economy	3.1 Economic performance	x	
	3.2 Quality	x	
	3.3 Digitization	x	

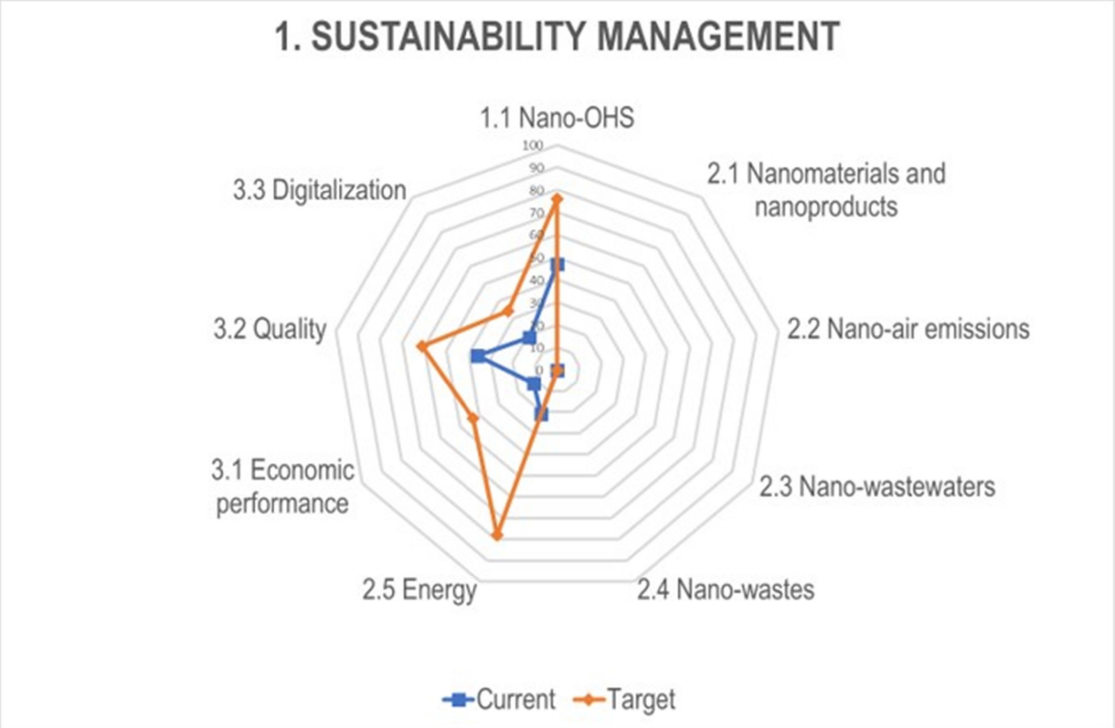

Figure B.1 — SNF implementation in OASIS-NPL1: sustainability management, dashboard

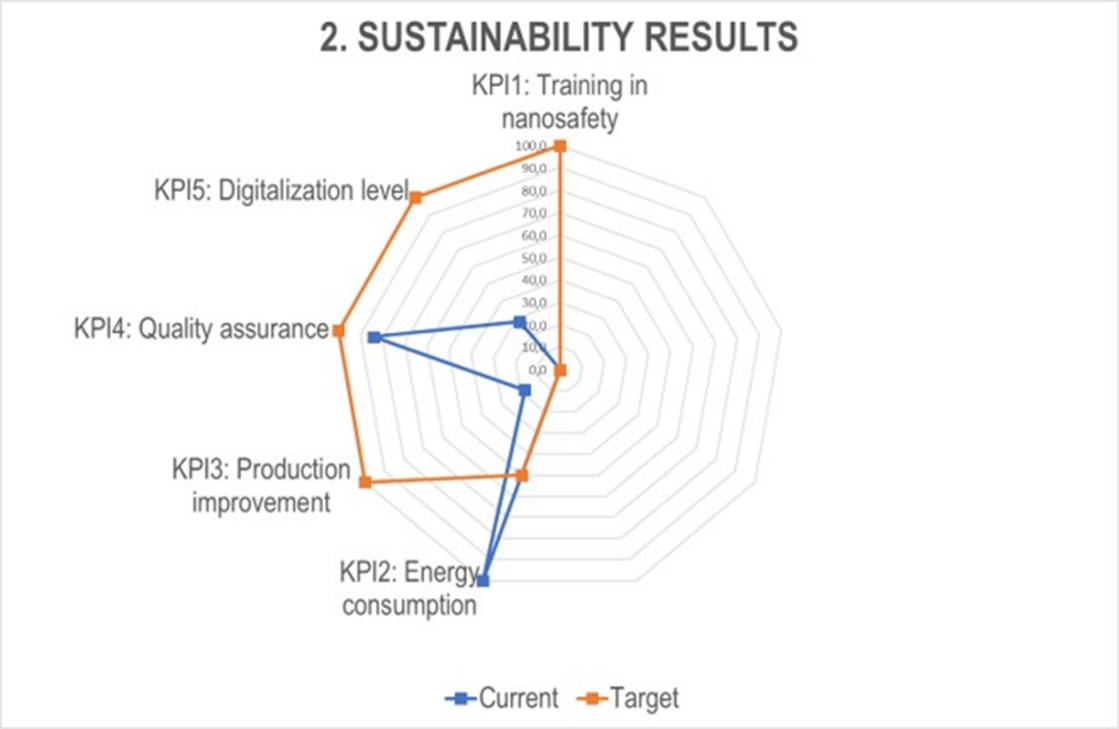

Figure B.2 — SNF implementation in OASIS-NPL1: sustainability results, dashboard

Table B.2 — SNF implementation in OASIS-NPL1: Improvement Plan

OASIS - SNF/IMPROVEMENT PLAN										
NPL1										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
1. Social	1.1 Nano-OHS	Increase the number of people and courses, conferences in Nanosafety that are taken by the working group (15)	Training in Nanosafety	1	Attending to the course about risk assessment and good practises from the prevention of occupational hazards group at ITQUIMA	01/01/2019	31/08/2022	Planned	NPL	NPL owner
				2	Planning and attending an specific training course about nanosafety imparted by CEA	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				3	Implementation of KPI1 monitoring	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
2. Environment	Energy	Reducing the energy consumption per batch (50%)	Energy consumption (kW·h)	1	Installation of an apparatus to measure the electricity consumption during the process	01/01/2019	31/08/2022	On going	Oasis project	NPL owner
				2	Installation of the LyoLogger software to detect the end of the primary drying step of the process	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				3	Protocols about good practices and maintenance of the Pilot Line for an efficient energy consumption	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				4	Optimization of the process parameters during the freeze-drying steps to reduce the energy consumption	01/01/2019	31/08/2022	On going	Oasis project	NPL owner
				5	Running the leak test of the Pilot Line recommended by the commercial company to ensure a good energy efficiency	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner

OASIS - SNF/IMPROVEMENT PLAN										
NPL1										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
				6	Implementation of KPI2 monitoring	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
. Economic	3.1 Economic performance	Increment from 0.36 m^2 up to 2 m^2 of aerogel produced per batch	Production improvement (m^2 aerogel/batch)	1	Redesign of the Pilot Line to increase the aerogel production	01/01/2019	31/08/2022	On going	Oasis project	NPL owner
				2	Assembly of more adequate trays for the Pilot Line	01/01/2019	31/08/2022	On going	Oasis project	NPL owner
				3	Implementation of KPI3 monitoring	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
	3.2 Quality	Increment of non-defected percentage of aerogel panels that accomplish the conductivity and density standard values (80-95 %)	Quality assurance (%)	1	Identification of the defected products	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				2	Acceptance and rejection criteria of the areogels produced. For not to be considered as a defected aerogel, their density and thermal conductivity values have to be in the range: density (0.001< aerogel < 0.1) g/cm^3; thermal conductivity (0.015 < aerogel < 0.070) W/(m·K)	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				3	Measurement procedure of conductivity and density of the different aerogels	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				4	Registration of the density and conductivity values	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				5	Technical maintenance from the commercial supplier to assure that the Pilot Line is	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner

OASIS - SNF/IMPROVEMENT PLAN										
NPL1										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
					working correctly, obtaining a high quality material					
				6	Installation of temperature sensors to measure the temperature of each tray in the Pilot Line and assure that all aerogels are produced at the same temperature	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				7	Implementation of KPI4 monitoring	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
	3.3 Digitalisation	Improvement of the digitalization level till 34 % (SI 3.3)	Digitalization level	1	Installation of the LyoLogger software	01/01/2019	31/08/2022	On going	Oasis project	NPL owner
				3	Registration of the process parameters automatically	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				3	Live monitoring of the process parameters	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				4	Exporting of the process parameters data	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner
				5	Implementation of KPI5 monitoring	01/01/2019	31/08/2022	Planned	Oasis project	NPL owner

B.3 Use Case 2: Diagnosis (Step 0) and Planning (Step 1) performed in a Nanomanufacturing Pilot Line dedicated to the synthesis of magnetic and flame retardant nanoparticles

B.3.1 General

As a practical use case, Table B.3, Figure B.3, Figure B.4 and Table B.4 summarize the results of the diagnosis performed with the SNF in the OASIS NPL3, dedicated to the synthesis of magnetic and flame retardant nanoparticles.

B.3.2 NPL3 in brief

In short, NPL3 is a TRL4 unit for magnetic and flame retardant nanoparticle synthesis. The NPL capacity is up to 1.5 kg/h with a yield in respect of iron sulphate approximately 92%. The pilot reactor is able to produce batch sizes up to 100 kg. The development of the NPL infrastructure was achieved by in cooperating new equipment to create new and larger supraparticles.

B.3.3 SNF customization and results

NPL3 customized the diagnosis of the SNF model, selecting the 3 SDs and six of the nine SIs ("nano-wastes", "energy" and "digitalization" were not selected as priorities at this time).

Regarding **Sustainability Management** in NPL3, there is a correct level of sustainability regarding the Nano-OHS item., and an average level of sustainability with a correct level regarding the nanomaterials and NEPs item. There is a significant range of improvement for the economy dimension, especially the economic performance items, but this item is not a priority for NPL3, which will focus on the other items. Therefore, NPL3 will improve the sustainability during OASIS especially in both OHS and environment dimensions. The results (%) obtained for the three SDs are respectively, 58 % (Social), 50 % (Environment) and 17 % (Economic). The relevant expected improvement rates at the end of the OASIS project for the three SDs range from 3% to 9%.

Six KPIs have been established by NPL3 to monitor **Sustainability Results**: KPI1: Percentage of workers properly trained to handle nanomaterials (% each year), KPI2: Number of emergency situations related to NMs and nanoproducts (spills, leaks, fire, explosion, etc) (number each month), KPI3: Number of inspections/audits to the shop floor where nano-air emissions are addressed (number per quarter year), KPI4: Nano-wastewaters generation per period considered (m3 each year), KPI5: Production capacity (kg/hour each year) and KPI6: Customer claims (number each year). The improvement ratios expected by these KPIs in 2022 range from 50% to 300% (e.g. KPI3 on nano-air emissions).

The calculated OASIS-SNFI is 41,1, and a score of 47 is predicted at the end of the project, representing a tangible improvement rate of 14%.

A suitable and feasible **Sustainability Improvement Plan** including 13 actions has been elaborated by NPL3 to achieve planned sustainability goals in the areas of Sustainability Management and Sustainability Results, and a Dashboard to monitor progress in both fields has also been established (see Figure B.3 and Figure B.4).

Table B.3 — SNF implementation in OASIS-NPL3: scope of the diagnosis

Dimension	Item	Yes	No
1 Social	1.1 OHS	x	
2. Environment	2.1 Materials	x	
	2.2 Air emissions	x	
	2.3 Wastewaters	x	
	2.4 Wastes		x
	2.5 Energy		x
3. Economy	3.1 Economic performance	x	
	3.2 Quality	x	
	3.3 Digitization		x

Figure B.3 — SNF implementation in OASIS-NPL3: sustainability management, dashboard

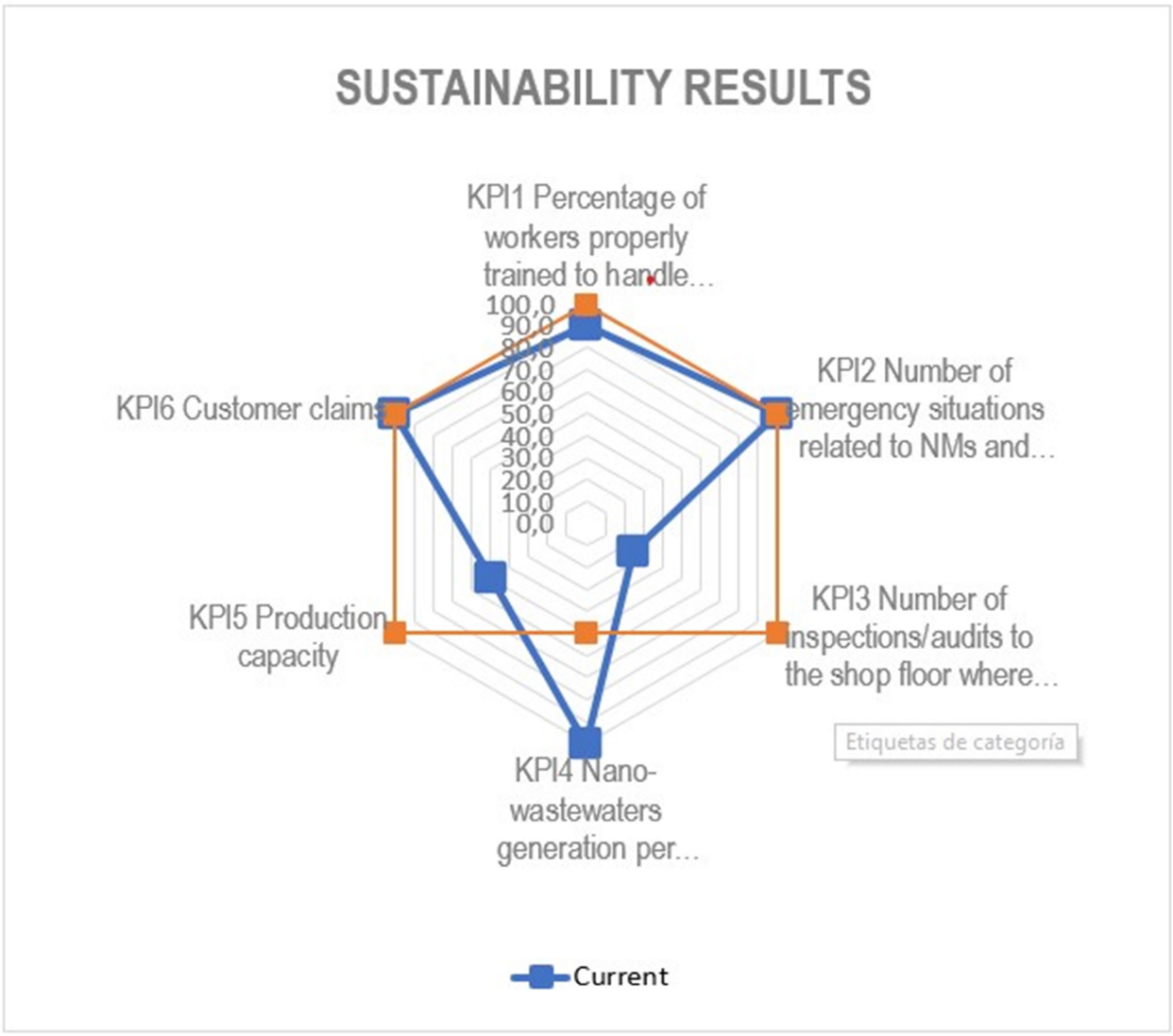

Figure B.4 — SNF implementation in OASIS-NPL3: sustainability results, dashboard

Table B.4 — SNF implementation in OASIS-NPL3: Improvement Plan

OASIS - SNF/IMPROVEMENT PLAN										
NPL3										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
1. Social	1.1 Nano-OHS	Employee Health	Not related to a KPI but to the sustainability management	1	Operating instructions before working with nanomaterials	all the time		100%		Safety department ISC:
				2	Safety equipment: FFP3 masks, gloves and safety clothing	all the time		100%		Safety department ISC
				3	Regulated access to sensitive areas	all the time		80%		Safety department ISC
		Increase by 11% the number of workers trained	Percentage of workers properly trained to handle nanomaterials	1	Safety training every year	01..01.2020	x	100%		Particle group ISC
				2	Development of operating instructions for every nanomaterial	01..01.2020	x	70%		Particle group ISC
2. Environment	2.1 NMs and NEPs	Keep the number of emergencies at 0.	Number of emergency situations related to NMs and nanoproducts	1	Safety training every year	01..01.2020		100%		Particle group ISC
				2	Regular examinations by the company doctor	all the time		80%		Safety department ISC
	2.2 Nano-air emissions	Increase by 300% the number of nano-air emission inspections	Number of inspections/audits to the shop floor where nano-air emissions are addressed	1	Measurement of the release of NP in the air	01..01.2020	x	50%	measurement system	Safety department ISC
	2.3 Nano-wastewaters	Reduce by 50% the annual wastewater	Nano-wastewaters generation per period considered	1	precipitation of stable nanoparticles before discharge into wastewater	all the time		100%		Particle group ISC
				2	Circulation of solvents	01/08/2019	01/10/2020	70%		Particle group ISC
3. Economic	3.1 Economic performance	Increase by 100% the production capacity	Production capacity	1	Cost plan establishment for SEP	01/06/2020	01/12/2020	20%	OASIS Members	Particle group ISC
				2	Measurement of the capacity increase annual	01/12/2020	x	50%		Particle group ISC
	3.2 Quality	Receive no complains	Customer claims	1	Establishment of an automated customer satisfaction survey	01/12/2020	x	10%		Particle group ISC

B.4 Use Case 3: Diagnosis (Step 0) and Planning (Step 1) performed in a Nanomanufacturing Pilot Line dedicated to the manufacture of buckypapers

B.4.1 General

As a practical use case, Table B.5, Figure B.5, Figure B.6 and Table B.6 summarize the results of the diagnosis performed with the SNF in the OASIS NPL4, dedicated to the manufacture of buckypaper. A buckypaper is a continuous self-supporting thin sheet/membrane, consisting of 100 % of entangled carbon nanotubes (CNTs).

B.4.2 NPL4 in brief

In short, NPL4 is a TRL6 new wet nanomanufacturing NPL, that uses vacuum filtration technology to manufacture a continuous buckypaper sheet, from an aqueous solution of MWCNTs prepared from a commercial customized waterborne dispersion.

The buckypaper is manufactured in rolls with various configurations in terms of length (up to 100 m) and widths (up to 300 mm), with a thickness between 30 and 150 µm.

B.4.3 SNF customization and results

NPL4 customized the diagnosis of the SNF model, selecting the 3 SDs and six of the nine SIs ("nano emissions to air", "nano-wastewater" and "energy" were not selected as priorities at this time).

Regarding **Sustainability Management** in NPL4, relevant management practices have been implemented in the OHS and Environmental dimensions, and to a lesser extent in the Economic dimension. Hot spots and streams connected with nano-OHS, nanomaterials and nanoproducts, and nano-wastes have been identified and evaluated in the NPL. A Safe-by-Design (SbD) approach has been followed in the design of NPL4 and a basic level of digitization has been reached in the NPL. The results (%) obtained for the three SDs are respectively, 65 % (Social), 58 % (Environment) and 36 % (Economic). Relevant improvement percentages around 20-25% for the three SDs, are expected at the end of the OASIS project.

Seven KPIs have been established by NPL4 to monitor **Sustainability Results**: KPI1 - Observed unsafe behaviours/work conditions (nano-OHS), KPI2 - CNT concentrate consumption intensity, KPI3 - Liquid-wastes containing CNTs traces (intensity), KPI4 - Buckypaper production, KPI5 - Annual turnover, KPI6 - Quality assurance and KPI7 - Level of digitalization. The improvement ratios expected by these KPIs in 2022 range from 5 to more than 100% (e.g. KPI4 on buckypaper production).

The calculated OASIS-SNFI is 53, and a score of 76 is predicted at the end of the project, representing a tangible improvement rate of 23%.

A suitable and feasible **Sustainability Improvement Plan** including 22 actions has been elaborated by NPL4 to achieve planned sustainability goals in the areas of Sustainability Management and Sustainability Results, and a Dashboard to monitor progress in both fields has also been established (see Figure B.5 and Figure B.6).

Table B.5 — SNF implementation in OASIS-NPL4: scope of the diagnosis

Dimension	Item	Yes	No
1 Social	1.1 OHS	x	
2. Environment	2.1 Materials	x	
	2.2 Air emissions		x
	2.3 Wastewaters		x
	2.4 Wastes	x	
	2.5 Energy		x
3. Economy	3.1 Economic performance	x	
	3.2 Quality	x	
	3.3 Digitization	x	

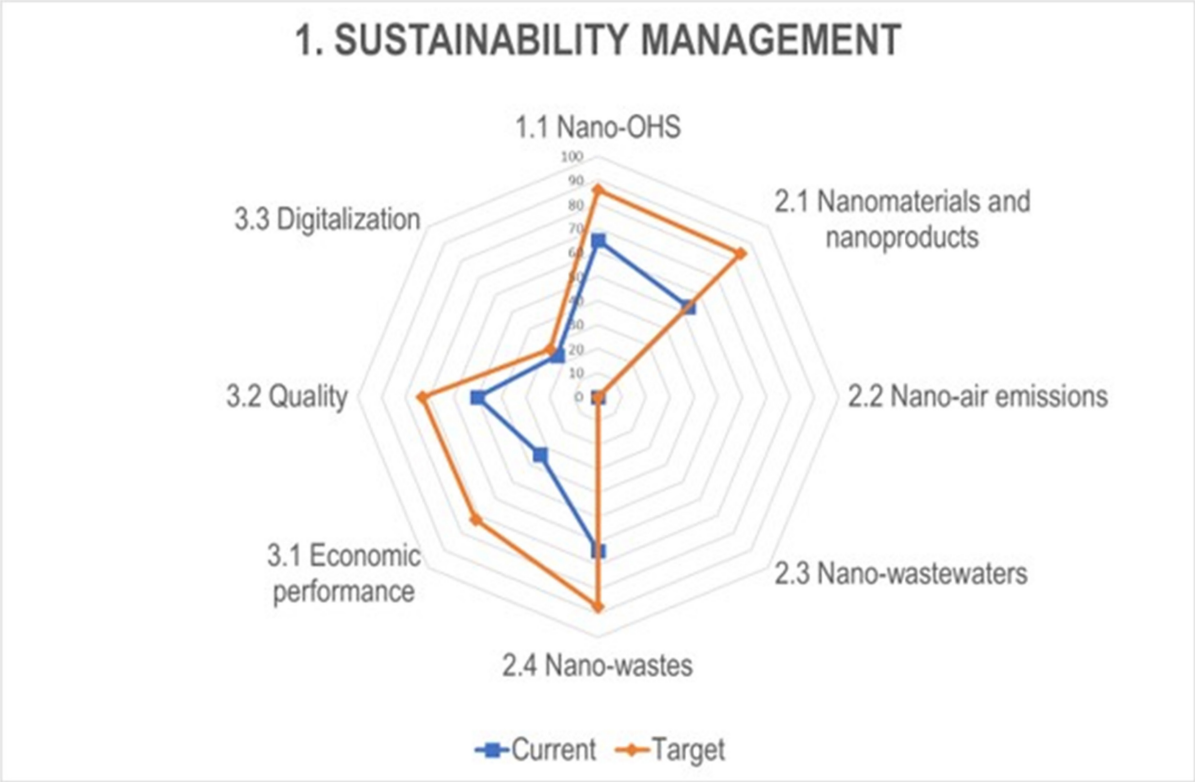

Figure B.5 — SNF implementation in OASIS-NPL4: sustainability management, dashboard

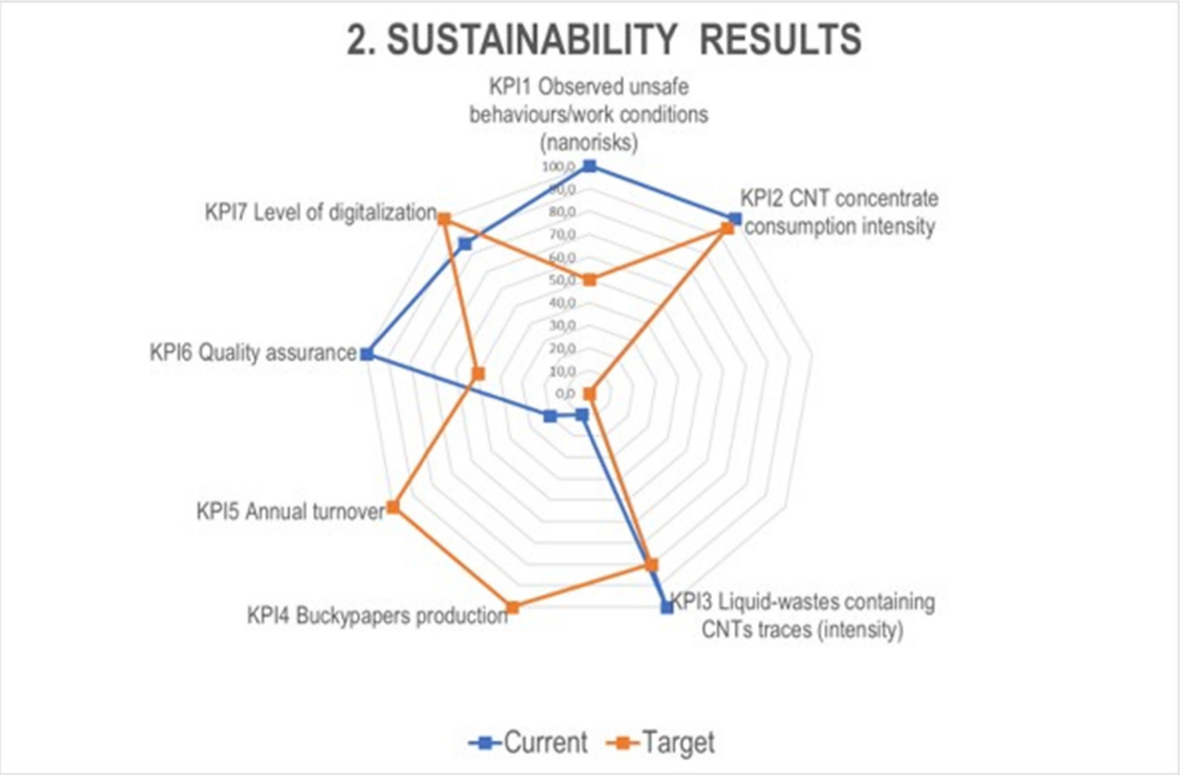

Figure B.6 — SNF implementation in OASIS-NPL4: sustainability results, dashboard

Table B.6 — SNF implementation in OASIS-NPL4: Improvement Plan

OASIS - SNF/IMPROVEMENT PLAN										
NPL4										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
1. Social	1.1 Nano-OHS	Reduce observed safety deviations with nanorisks (NIV)	KPI1. Observed unsafe behaviours/work conditions (nanorisks)	1	Adapt TECNALIA´s safety inspections (OHSMS) to NPL4, and carry them out monthly.	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				2	Compile and analyse regulatory requirements	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				3	Implementation of monitoring with KPI1	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
2. Environment	2.1 NMs and NEPs	Reduce consumption of CNTs by 5 %	KPI2. CNT concentrate (MB) consumption intensity (kg/kg)	1	The same activity as 2.4.1	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Substitution of part of the CNT content with additional materials	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				3	Update Buckypaper SDS	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				4	Implementation of KPI2 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
	2.4 Nano-wastes	Reduce liquid-wastes containing CNTs by 20 %	KPI3. Liquid-wastes containing CNTs traces (l/kg)	1	Develop and implement a system to recycle filtered waters and minimize waste production	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Implementation of KPI3 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
3. Economic	3.1 Economic performance	Increase production by 10	KPI4 Buckypapers production (m2/week)	1	NPL4 - upgrading and scaling activities, by integrating the modules and devices specified in T1.3 (WP1)	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				2	Implementation of KPI4 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
		Increase sales by 20 %	KPI5 Annual turnover (k€)	1	Increase the number of commercial visits among potential clients	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Study new industrial fields of application for the product	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				3	Increase added value of buckypaper (polymeric/metallic layers)	01/01/2019	31/08/2022	On going	OASIS project	NPL owner

OASIS - SNF/IMPROVEMENT PLAN										
NPL4										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
				4	Strengthen product dissemination actions	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				5	Implementation of KPI5 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
	3.2 Quality	Reduce quality defects (No initial KPI value)	KPI6 Defective products (Number)	1	Implement a procedure for product quality defects monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				2	Implement an analytical methodology for the characterization of input materials (CNTs, surfactant)	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
				3	Implementation of KPI6 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner
	3.3 Digitalisation	Increase digitalisation level by 20 %	KPI7 Level of digitalization (%)	1	Implement a digital system to monitor and control key process parameters	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				2	Implement a digital system to monitor and control dispersion preparation	01/01/2019	31/08/2022	On going	OASIS project	NPL owner
				3	Implementation of KPI7 monitoring	01/01/2019	31/08/2022	Planned	OASIS project	NPL owner

B.5 Use Case 4: Diagnosis (Step 0) and Planning (Step 1) performed in a Nanomanufacturing Pilot Line dedicated to modular pultrusion

B.5.1 General

As a practical use case, Table B.7, Figure B.7, Figure B.8 and Table B.8 summarize the results of the diagnosis performed with the SNF in the OASIS NPL12, dedicated to modular pultrusion, capable of processing various types of resin (mainly Thermoset) and fibre systems.

B.5.2 NPL12 in brief

In short, NPL12 is a TRL5 modular pultrusion line that is capable of processing various types of resin (mainly Thermoset) and fibre systems. Modular components involve different puller/ caterpillar systems, a braiding wheel for braided/winded tubes or rods, different injection systems for closed injection pultrusion, open bath chambers and connected fibre guidance modules, as well as various tooling for development trials.

B.5.3 SNF customization and results

NPL12 customized the diagnosis of the SNF model, selecting the 3 SDs and six of the nine SIs ("nano wastes", "energy" and "digitalization" were not selected as priorities at this time).

Regarding **Sustainability Management** in NPL12, an average level of sustainability has been achieved, with a correct level regarding the Nano-OHS and the nanomaterials and NEPs items. Nevertheless, NPL12 has a range of improvement for the sustainability regarding the nano-air emissions item. There is a significant range of improvement for the economy dimension, especially the economic performance items. However, this item is not a priority for this Pilot Line, and therefore only one action will be implemented. The results (%) obtained for the three SDs are respectively, 72 % (Social), 42 % (Environment) and 16 % (Economic). The relevant improvement percentages expected at the end of the OASIS project range from 2% to 16% for the three SDs.

Five KPIs have been established by NPL12 to monitor **Sustainability Results**: KPI1: Percentage of workers properly trained to handle nanomaterials (% each year), KPI2: Nanomaterials and nanoproducts consumption (Kg/quarter year), KPI3: Number of measurement (number per project), KPI4: Production speed (m of rebars/min per month) and KPI5: Defective products (percentage each month). The improvement ratios expected by these KPIs in 2022 range from 100% to 200%.

The calculated OASIS-SNFI is 43,1, and a score of 54 is predicted at the end of the project, representing a tangible improvement rate of 25%.

A suitable and feasible **Sustainability Improvement Plan** including 11 actions has been elaborated by NPL12 to achieve planned sustainability goals in the areas of Sustainability Management and Sustainability Results, and a Dashboard to monitor progress in both fields has also been established (see Figure B.7 and Figure B.8).

Table B.7 — SNF implementation in OASIS-NPL12: scope of the diagnosis

Dimension	Item	Yes	No
1 Social	1.1 OHS	x	
2. Environment	2.1 Materials	x	
	2.2 Air emissions	x	
	2.3 Wastewaters	x	
	2.4 Wastes		x
	2.5 Energy		x
3. Economy	3.1 Economic performance	x	
	3.2 Quality	x	
	3.3 Digitization		x

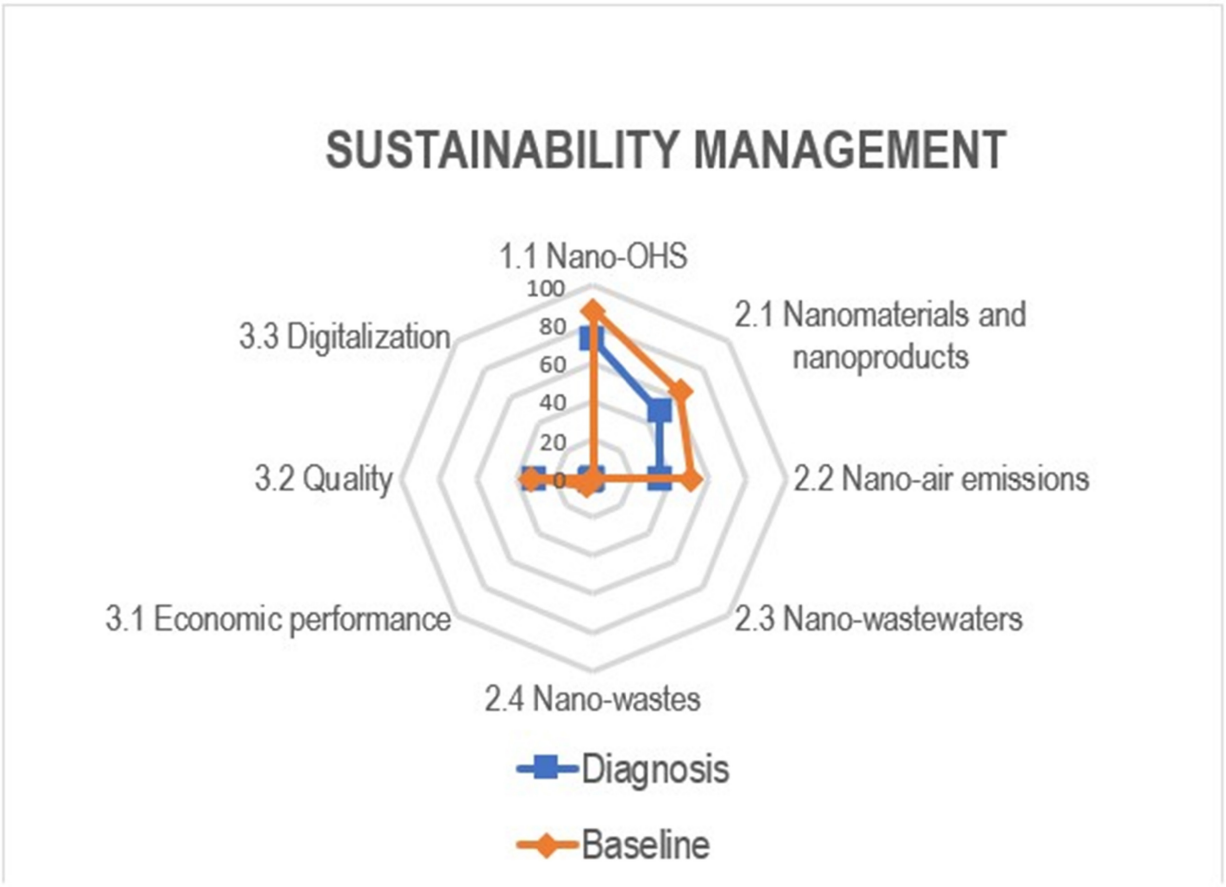

Figure B.7 — SNF implementation in OASIS-NPL12: sustainability management, dashboard

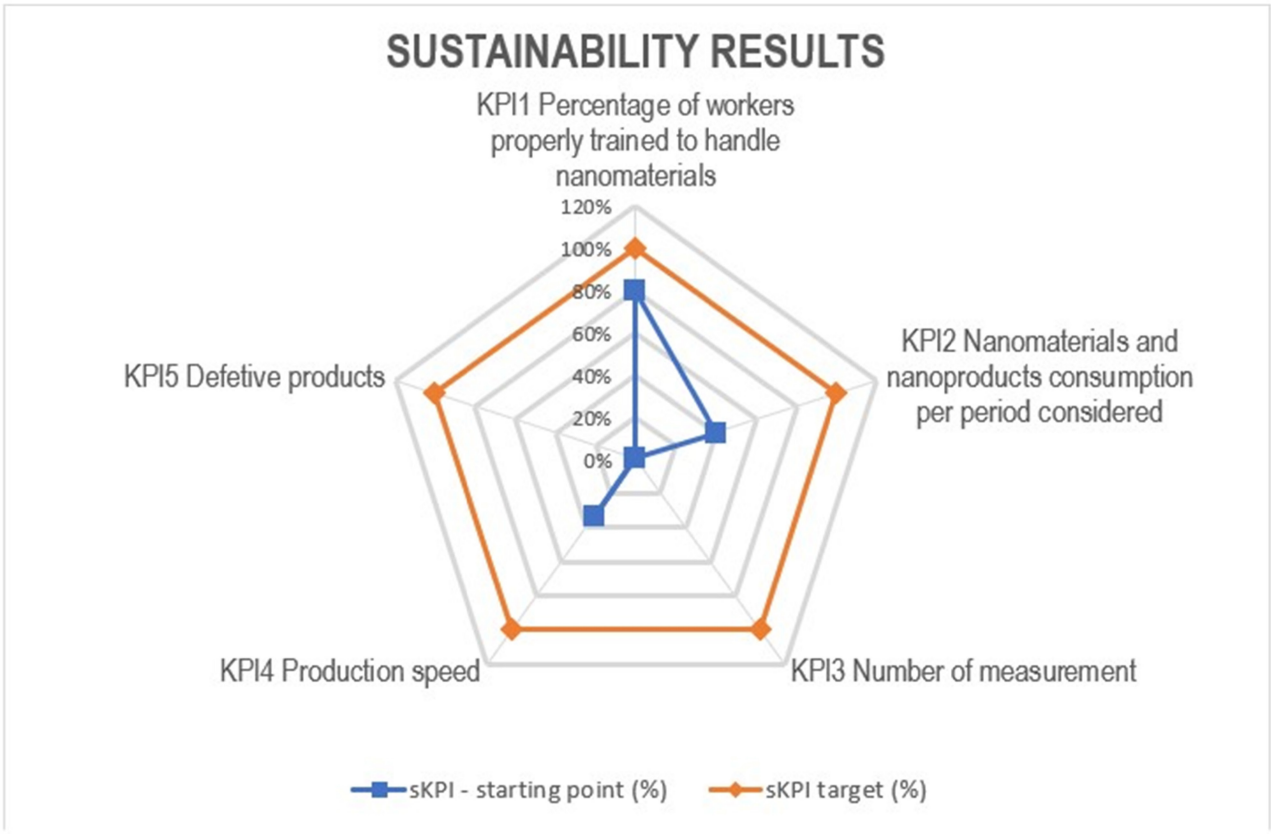

Figure B.8 — SNF implementation in OASIS-NPL12: sustainability results, dashboard

Table B.8 — SNF implementation in OASIS-NPL12: Improvement Plan

OASIS - SNF/IMPROVEMENT PLAN										
NPL12										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
1. Social	1.1 Nano-OHS	Increase by 25% the number of workers trained per year	Percentage of workers properly trained to handle nanomaterials	1	Written work instructions	01/10/2020	30/11/2020		hazardous substances officer	OHS manager
				2	Definition of working people	01/10/2020	30/11/2020			OHS manager
				3	Instruction	01/10/2020	30/11/2020			OHS manager
2. Environment	2.1 NMs and NEPs	Increase by 150% the weight of nano consumption per quarter year	Nanomaterials and nanoproducts consumption per period considered	1	Excel calculation tool	01/10/2020	31/12/2020			Manager of environmental issues
	2.2 Nano-air emissions	Increase by 100% the number of measurement performed in 4 years	Number of measurement	1	Measurement at IGCV or Acciona	06/12/2021	10/12/2021		CEA	Manager of environmental issues
				2	Evaluation and discussion of the measurements	13/12/2021	31/08/2022		CEA	Manager of environmental issues
3. Economic	3.1 Economic performance	Increase by 200% the production speed per month	Production speed	1	Test with IR heaters	01/07/2020	30/10/2020			Manager of the NPL
				2	Test with Inductive heater	01/07/2020	30/10/2020			Manager of the NPL
				3	Energy consumption	01/07/2020	30/10/2020			Manager of the NPL
				4	Process parameter improvements	01/07/2020	30/10/2020			Manager of the NPL
	3.2 Quality	Reduce by 100% the number of defective products	Defective products	1	Finding the process window	01/07/2020	30/11/2020			Manager of the NPL

Annex C
(informative)

Use Cases of diagnosis (step 0) and planning (step 1) of Nanomanufacturing Pilot Lines of the INNOMEM project (EU-project INNOMEM– GA 862330).

C.1 Introduction

This Annex C shows two use cases of the INNOMEM project (GA Nº 814581) where NPLs used the SNF for the initial diagnosis of the sustainability of their processes and to draft their improvement plans.

C.2 Use Case 1: Diagnosis (Step 0) and Planning (Step 1) performed in a Nanomanufacturing Pilot Line dedicated to the Mixed Matrix Hollow Fiber Membranes production

C.2.1 General

As a practical use case, Table C.1, Figure C.1, Figure C.2 and Table C.2 summarize the results of the diagnosis performed with the SNF in the INNOMEM NPL1, dedicated to the manufacture of mixed matrix hollow fiber membranes. A MMM HFs is a hollow fiber of less than 0.6 mm outside diameter made by a polymer in which Metal Organic Frameworks has been added.

C.2.2 NPL1 in brief

In short, NPL1 is a TRL6 Mixed Matrix HF spinning system for gas separation membrane manufacturing able to produce single and dual layer mixed matrix membranes for improving the permeability and selectivity in gas separation. After upgrading, continuous production will be possible with higher production capacity and at higher spinning temperature. Online monitoring of spinning parameters is foreseen

C.2.3 SNF customization and results

NPL1 customized the diagnosis of the SNF model, selecting the 3 SDs and six of the nine SIs ("nano airborne emissions", "energy" and "economic performance" were not selected as priorities at this time). See Table B.1.

Regarding **Sustainability Management** in NPL1, relevant management practices have been implemented in the OHS, Environmental and Economic dimensions (Figure B.1). Hot spots and streams connected with nano-OHS, nanomaterials and nanoproducts, nano-wastewaters, and nano-wastes have been identified and evaluated in the NPL. A high increase of digitization will be reached in the NPL by the end of the project. The results (%) obtained for the three SDs are respectively, 56 % (Social), 45.6 % (Environment) and 6.5 % (Economic). Relevant improvement percentages around 20-29% for the three SDs, are expected at the end of the INNOMEM project.

Six KPIs have been established by NPL1 to monitor **Sustainability Results**: KPI1: Risk assessments on OHS risks completed or reviewed, KPI2: Percentage of workers with adequate NMs or NPs manipulation training, KPI3: Wastewater intensity, KPI4: Nano-wastes intensity, KPI5: Hollow fiber production, KPI6: Level of digitalization. Extensive improvement is foreseen, especially in SD Economy, where the hollow fiber production will be increased by a factor of 35, from 200 m/batch up to 7000 m/batch. Wastewater and nano-wastes intensity will be decreased by 34% and 45% respectively. The level of digitalization will be increased from 0 to 90%. Proper OHS risk assessment will be performed, and adequate training on handling NMs and NPs will be implemented.

The calculated INNOMEM-SNFI is 35.7, and a score of 59.1 is predicted at the end of the project, representing a tangible improvement rate of 23.4%.

A suitable and feasible **Sustainability Improvement Plan** including 21 actions has been elaborated by NPL1 to achieve planned sustainability goals in the areas of Sustainability Management and Sustainability Results, and a Dashboard to monitor progress in both fields has also been established (see Table C.2 and Figure C.2).

Table C.1 — SNF implementation in INNOMEM-NPL1: scope of the diagnosis

Dimension	Item	Yes	No
1 Social	1.1 OHS	x	
2. Environment	2.1 Nanomaterials and nanoproducts	x	
	2.2 Nano-airborne emissions		x
	2.3 Nano-wastewaters	x	
	2.4 Nano-wastes	x	
	2.5 Energy		x
3. Economy	3.1 Economic performance	x	
	3.2 Quality		x
	3.3 Digitalization	x	

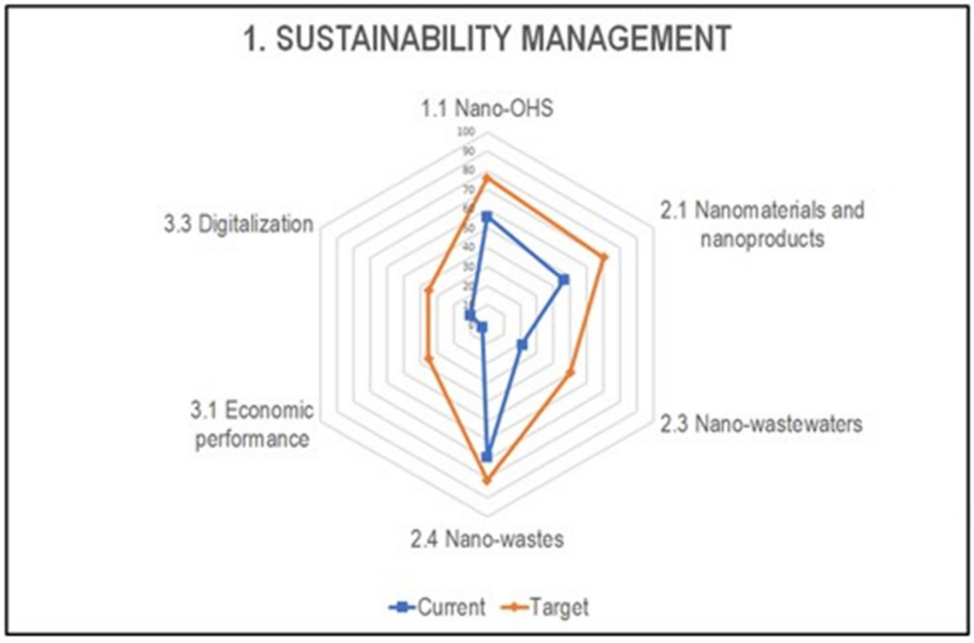

Figure C.1 — SNF implementation in INNOMEM-NPL1: sustainability management, dashboard

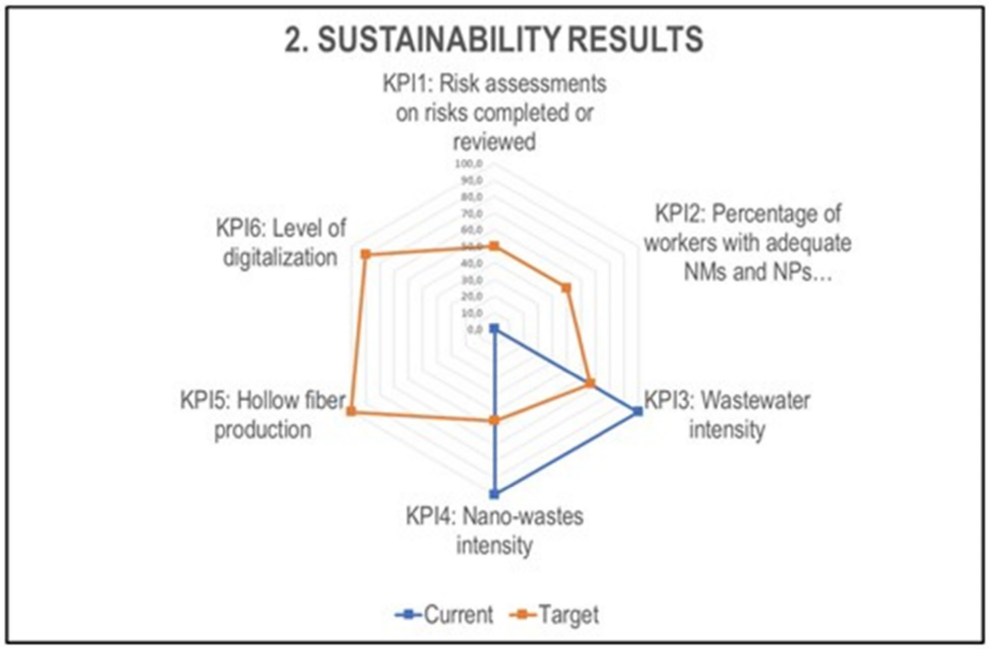

Figure C.2 — SNF implementation in INNOMEM-NPL1: sustainability results, dashboard

Table C.2 — SNF implementation in INNOMEM-NPL1: Improvement Plan

INNOMEM - SNF/IMPROVEMENT PLAN										
NPL1										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
1. SOCIAL	1.1 Nano-OHS	Complete the documentation related to Risk assessments	KPI1: Risk assessments on risks completed or reviewed	1	Document the potential emergency situations of the PL and how to deal with them (included in the SOP of the PL1).	01/05/2020	31/10/2023	On going	INNOMEM project	NPL owner
				2	Improve the RA of the spinning line and check periodically (Annually)	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				3	Look for legal/regulatory requirements information about nanoparticles utilization	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				4	Draft a SDS for the final product (polymeric or mixed matrix hollow fiber membranes)	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				5	Implementation of KPI1 monitoring	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
2. ENVIRONMENT	2.1 Nanomaterials and nanoproducts	Train 100% of the workers associated to the PL on NMs and NPs manipulation	KPI2: Percentage of workers with adequate NMs and NPs manipulation training	1	Identify a course on NM and NP manipulation	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				2	Training course for workers	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				3	Define a systematic reagents/effluents management procedure	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner

INNOMEM - SNF/IMPROVEMENT PLAN										
NPL1										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
				4	Implementation of KPI2 monitoring	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
	2.3 Nano-wastewaters	Reduce 30% the wastewater produced per meter of product manufactured	KPI3: Wastewater intensity	1	PL1 upgrading activities. By a new design of the coagulation bath and the implementation of multiple orifice spinneret, wasterwater produces per meter of fibers will be significantly reduced.	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				2	Characterize and quantify nano-wastewaters flows. Identification of regulatory requirements on nano-wastewaters. Based on this analysis, implement equipment and systems for nano-wastewaters prevention and control (if required)	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				3	Implementation of KPI3 monitoring	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
	2.4 Nano-wastes	Reduce 40% the dope solution wasted per meter of product manufactured	KPI4: Nano-wastes intensity	1	PL1 upgrading activities (dope reactor)	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				2	Implementation of KPI4 monitoring	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner

INNOMEM - SNF/IMPROVEMENT PLAN										
NPL1										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
3. ECONOMIC	3.1 Economic performance	Increase production per batch by 35	KPI5: Hollow fiber production (m/batch)	1	PL1 upgrading activities (whole spinning system)	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				2	Stablish a costing system for the PL and the product cost based on that	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				3	Perform a benchmark of our final products prices based on open literature data	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				4	Implementation of KPI5 monitoring	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
	3.3 Digitalisation	Increase digitalisation level by 90%	KPI6 Level of digitalization (%)	1	Implement a control system to online monitored and registered all spinning parameters	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				2	Register the calibration information on thein the CMMS of Tecnalia	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				3	Implementation of KPI6 monitoring	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner

C.3 Use Case 2: Diagnosis (Step 0) and Planning (Step 1) performed in a Nanomanufacturing Pilot Line dedicated to Pd-based membranes production

C.3.1 General

As a practical use case, Table C.3, Figure C.3, Figure C.4 and Table C.4 summarize the results of the diagnosis performed with the SNF in the INNOMEM NPL2, dedicated to the manufacture of Pd-based membranes on tubular supports. A Pd-based membranes is a tubular membrane including Pd and other elements as well as nanostructured material.

C.3.2 NPL2 in brief

This Pilot Line produces thin Pd-based membranes on tubular supports by electroless plating, for hydrogen gas separation with high permeance and selectivity. After upgrading, pre-processing and plating steps are automated and integrated to increase production capacity. Automated quality assurance is foreseen by process control and integration of non-destructive membrane characterisation.

C.3.3 SNF customization and results

NPL2 customized the diagnosis of the SNF model, selecting the 3 SDs and six of the nine SIs ("nano airborne emissions", "nano-wastes" and "energy" were not selected as priorities at this time). See Table B.3.

Regarding **Sustainability Management** in NPL2, relevant management practices have been implemented in the OHS, Environmental and Economic dimensions (Figure C.3). Hot spots and streams connected with nano-OHS, nanomaterials and nanoproducts, nano-wastewaters have been identified and evaluated in the NPL. An increase of production capacity and automatization as well as a decrease of defective products will be achieved in the NPL by the end of the project. The results (%) obtained for the three SDs are respectively, 56 % (Social), 56.5 % (Environment) and 31.4 % (Economic). Relevant improvement percentages around 17.5-22% for the three SDs, are expected at the end of the INNOMEM project.

Six KPIs have been established by NPL1 to monitor **Sustainability Results**: KPI1: Frequency unsafe behaviour, KPI2: Reagents consumption, KPI3: Water intensity, KPI4: Pd membrane production, KPI5: Defective Pd membranes, KPI6: Process steps with automatic process control (PLC or other). Extensive improvement is foreseen, especially in SD Economy, where the Pd membrane production will be increased by a factor of 4, from 4 up to 16 membranes/week, the number of process steps with automatic process control will rise from 10% to 80%, and the number of defective membranes will be diminished by a factor of 2. Further the Pilot Line aims for a small reduction in reagent consumption (4%). Water intensity and frequency of unsafe behaviour will be monitored for the first time, to limit them to 0,18 m^3/m^2 and to maximum 2, respectively.

The calculated INNOMEM-SNFI is 47.8, and a score of 67.9 is predicted at the end of the project, representing a tangible improvement rate of 20.1%.

A suitable and feasible **Sustainability Improvement Plan** including 30 actions has been elaborated by NPL2 to achieve planned sustainability goals in the areas of Sustainability Management and Sustainability Results, and a Dashboard to monitor progress in both fields has also been established (see Table C.4 and Figure C.4).

Table C.3 — SNF implementation in INNOMEM-NPL2: scope of the diagnosis

Dimension	Item	Yes	No
1 Social	1.1 OHS	x	
2. Environment	2.1 Nanomaterials and nanoproducts	x	
	2.2 Nano-airborne emissions		x
	2.3 Nano-wastewaters	x	
	2.4 Nano-wastes		x
	2.5 Energy		x
3. Economy	3.1 Economic performance	x	
	3.2 Quality	x	
	3.3 Digitalization	x	

Figure C.3 — SNF implementation in INNOMEM-NPL2: sustainability management, dashboard

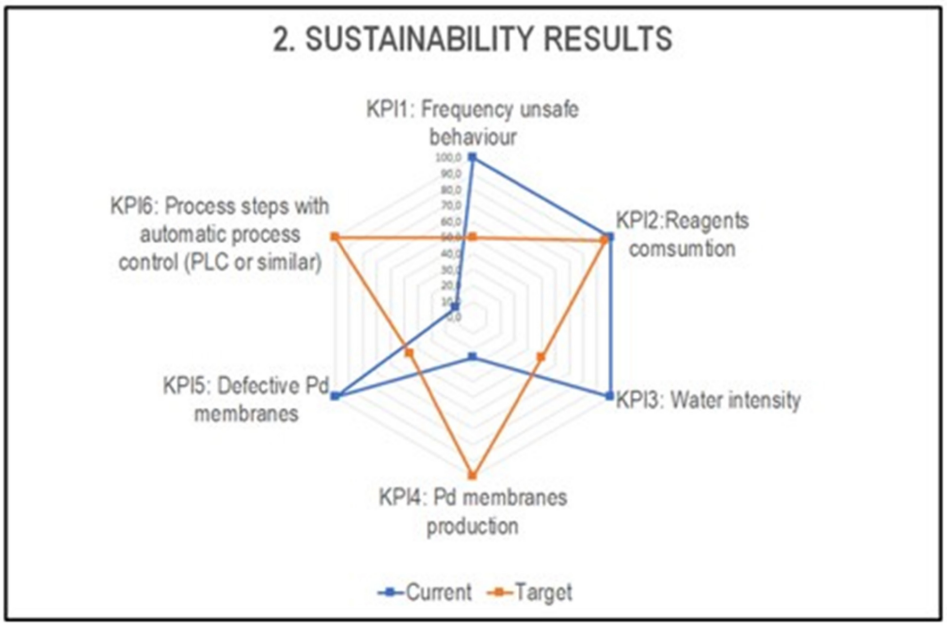

Figure C.4 — SNF implementation in INNOMEM-NPL2: sustainability results, dashboard

Table C.4 — SNF implementation in INNOMEM-NPL2: Improvement Plan

INNOMEM - SNF/IMPROVEMENT PLAN										
NPL2										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
1. SOCIAL	1.1 Nano-OHS	Reduce the unsafe behaviour in Pd-based membranes manufacturing	KPI1.Frequency of observed unsafe behaviour (Nº/year)	1	Collect regulatory documentation	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				2	re-evaluation and update of Risk Assessment and Safety report	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				3	Implement an incident notebook included in the safety report	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				4	Implementation of a preventive and action plan in the event of an accident in accordance with the Safety reports.	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				5	Implementation of monitoring with KPI1	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
2. ENVIRONMENT	2.1 Nanomaterials and nanoproducts	Reduce Reagents consumption in 3,6% in Pd based pilot line	KPI2.Reagents consumption (kg/m2)	1	Re-design and substitution of the plating process reactor.	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				2	Update the plating process based on the PL02	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				3	Develop specific procedure for product management based on the general Tecnalia procedure	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				4	Implementation of monitoring with KPI2	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
	2.3 Nano-wastewaters	Control water consumption in 0,22 m3/m2	KPI3.Water intensity (m3/m2)	1	Update the plating process based on the PL02	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner

INNOMEM - SNF/IMPROVEMENT PLAN										
NPL2										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
				2	Collect regulatory documentation	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				3	Implement a system to quantify the water consumed during the process like a water meter in the feed system of the pilot line.	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				4	Implementation of monitoring with KPI3	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
3. ECONOMIC	3.1 Economic performance	Increase production by 4	KPI4. Production (Nº/week)	1	Re-design and substitution of the plating process reactor.	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				2	Update the plating process based on the PL02	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				3	Establish a monitoring system on the sales plan	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				4	Establish an improvement plan that includes a register of process efficiency, use of materials and a monitoring plan	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				5	Implementation of monitoring with KPI4	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
	3.2 Quality	Reduce defective	KPI5. Defective products (%)	1	Re-design and substitution of the plating process reactor.	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner

INNOMEM - SNF/IMPROVEMENT PLAN										
NPL2										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
		membranes in (46%)		2	Update the plating process based on the PL02	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				3	Implementation of a continuous process data recording system	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				4	Develop of a process for recovering defective membranes	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				5	Development of a procedure for managing the reception of raw materials and their storage, including acceptance conditions (non-conformities)	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				6	Development of a procedure to follow up (traceability) of the material supplied to the client	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				7	Implementation of monitoring with KPI5	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
	3.3 Digitalisation	Increase of process steps with automatic control in 80%	KPI6. Process steps with automatic process control (PLC or similar) (%)	1	Implementation of automatic process control based on PLC system	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				2	Replacement of manually operated auxiliary equipment with fully automatic components (pumps, level sensors, etc.)	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner

INNOMEM - SNF/IMPROVEMENT PLAN										
NPL2										
SD	**SI**	**Objective**	**KPI**	**Activity**		**Start date**	**End date**	**Status**	**Resources**	**Responsible**
				3	Implementation of a calibration/maintenance procedure accordance with the CMMS of Tecnalia.	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner
				4	Implement a control system to online monitored and registered all parameters	01/05/2020	30/04/2022	On going	INNOMEM project	NPL owner
				5	Implementation of monitoring with KPI6	01/05/2020	31/10/2023	Planed	INNOMEM project	NPL owner

Bibliography

[1] EN ISO 9000:2015, *Quality management systems - Fundamentals and vocabulary (ISO 9000:2015)*

[2] EN ISO 9001:2015, *Quality management systems - Requirements (ISO 9001:2015)*

[3] EN ISO 14001:2015, *Environmental management systems — Requirements with guidance for use*

[4] EN ISO 14004:2016, *Environmental management systems — General guidelines on implementation*

[5] EN ISO 14050:2020, *Environmental management - Vocabulary (ISO 14050:2020)*

[6] EN ISO 14050:2020/prA1, *Environmental management - Vocabulary - Amendment 1 (ISO 14050:2020/DAM 1:2022)*

[5] ISO 6707-3:2017, *Buildings and civil engineering works — Vocabulary — Part 3: sustainability terms*

[6] ISO/FDIS 6707-3, *Buildings and civil engineering works — Vocabulary — Part 3: sustainability terms*[under development]

[7] ISO 10014:2021, *Quality management systems — Managing an organization for quality results — Guidance for realizing financial and economic benefits*

[8] ISO 10987:2012, *Earth-moving machinery — Sustainability — terminology, sustainability factors and reporting*

[9] ISO 10987-2:2017, *Earth-moving machinery — Sustainability — Part 2: remanufacturing*

[10] ISO 10987-3:2017, *Earth-moving machinery — Sustainability — Part 3: used machines*

[11] ISO 13065:2015, *Sustainability criteria for bioenergy*

[12] ISO 15392:2019, *Sustainability in buildings and civil engineering works — General principles*

[13] ISO 16745-1:2017, *Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — part 1: calculation, reporting and communication*

[14] ISO 16745-2:2017, *Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — part 2: verification*

[15] ISO 17889-1:2021, *Ceramic tiling systems — Sustainability for ceramic tiles and installation materials — Part 1: Specification for ceramic tiles*

[16] EN ISO 17989-1:2015, *Tractors and machinery for agriculture and forestry — sustainability — Part 1: principles*

[17] ISO 20140-1:2019, *Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment — Part 1: Overview and general principles*

[18] ISO 20400:2017, *Sustainable procurement — Guidance*

[19] ISO/TR 21506:2018, *Project, programme and portfolio management — Vocabulary*

[20] ISO 21678:2020, *Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements and guidelines*

[21] ISO/DIS 21928-2, *Sustainability in buildings and civil engineering works — Sustainability indicators — Part 2: framework for the development of indicators for civil engineering works*[under development]

[22] ISO 21929-1:2011, *Sustainability in building construction — Sustainability indicators — part 1: framework for the development of indicators and a core set of indicators for buildings*

[23] ISO/TS 21929-2:2015, *Sustainability in building construction — Sustainability indicators — Part 2: framework for the development of indicators for civil engineering works*

[24] ISO 21931-1:2022, *Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 1: buildings*

[25] ISO 21931-2:2019, *Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: civil engineering works*

[26] ISO/TR 21932:2013, *Sustainability in buildings and civil engineering works — A review of terminology*

[27] ISO 22400-1:2014, *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 1: Overview, concepts and terminology*

[28] ISO 22400-2:2014, *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 2: Definitions and descriptions*

[29] ISO 22400-2:2014/Amd.1:2017, *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management —Part 2: Definitions and descriptions. AMENDMENT 1: Key performance indicators for energy management*

[30] ISO/TR 22400-10:2018, *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management —Part 10: Operational sequence description of data acquisition*

[31] ISO 23405:2022, *Tourism and related services — Sustainable tourism — Principles, vocabulary and model*

[32] ISO 23434-1:2021, *Industrial trucks — Sustainability — Part 1: Vocabulary*

[33] ISO 23434-2:2021, *Industrial trucks — Sustainability — Part 2: Factors and reporting*

[34] ISO 37101:2016, *Sustainable development in communities — management system for sustainable development — Requirements with guidance for use*

[35] ISO 45001:2018, *Occupational health and safety management systems — Requirements with guidance for use*

[36] ISO/TS 80004-1:2015, *Nanotechnologies — Vocabulary — Part 1: Core terms*

[37] ISO/DIS 80004-1, *Nanotechnologies – Vocabulary — Part 1: Core terms and definitions*[under development]

[38] ISO Guide 82:2019, *Guidelines for addressing sustainability in standards*

[39] ISO/IWA 19:2017, *Guidance principles for the sustainable management of secondary metals*

[40] UNE 0060:2018, *Industry 4.0. Management system for digitization. Requirements*.

[41] UNE 0061:2019, *Industry 4.0. Management system for digitization. Requirements assessment*

[42] UNE 166002:2021, *R&D&i management: R&D&i management system requirements*

[43] ASTM Standards on sustainable manufacturing https://www.astm.org/Standards/sustainability-standards.html

[44] OECD. (2011) OECD Sustainable Manufacturing Toolkit. Start-up Guide: Seven steps to environmental excellence. OECD Directorate for Science, Technology and Industry (DSTI), 51 pp. https://www.oecd.org/innovation/green/toolkit/48704993.pdf

[45] EC (2000) Communication from the Commission on the precautionary principle COM (2000) 1 final Brussels, 2.2.2000

[46] EC. (2020) EU-Sustainable production and consumption. https://ec.europa.eu/jrc/en/research-topic/sustainable-production-and-consumption

[47] European Commission. Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Pilot production in Key Enabling Technologies, Publications Office, 2017, https://data.europa.eu/doi/10.2873/944439

[48] EU. (2020) Smart Specialization Platform (S3 Platform), Efficient and Sustainable Manufacturing. https://s3platform.jrc.ec.europa.eu/efficient-and-sustainable-manufacturing?inheritRedirect=true

[49] Sustainable manufacturing initiative: U.S. Department of Commerce. International Journal of Powder Metallurgy 47(1):12-16 January 2011

[50] U.S. Department of Commerce (2008). Sustainable manufacturing initiative

http://www.trade.gov/competitiveness/sustainablemanufacturing/how_doc_defines_SM.asp

[51] US EPA (2017) Glossary of Sustainable Manufacturing Terms, and tools

https://www.epa.gov/sustainability/sustainable-manufacturing

https://www.epa.gov/e3/e3-sustainability-tools

[52] Garretson I.C., Mani M., Leong S., Lyons K.W., Haapala K.R. Terminology to support manufacturing process characterization and assessment for sustainable production. J. Clean. Prod. 2016, 139 pp. 986–1000

[53] Hauschild M., Dornfeld D., Hutchins M., Kara S., Jovane F. (2014) Sustainable Manufacturing. CIRP Encyclopedia of Production Engineering, 2014 Edition

[54] López de Ipiña J.M., Hernan A., Cenigaonaindia X., Insunza M., Florez S., Seddon R. et al. (2017) Implementation of a safe-by-design approach in the development of new open pilot lines for the manufacture of carbon nanotube-based nano-enabled products. IOP Conf. Series: Journal of Physics: Conf. Series 838 (2017) 012018

[55] MANUFUTURE (2018) ManuFUTURE-Vision 2030. Competitive, sustainable and resilient European manufacturing

[56] Massachusetts University – Lowell Center (2017) What is sustainable manufacturing?

[57] Moldavskaab A., Welob T. The concept of sustainable manufacturing and its definitions: A content-analysis based literature review. J. Clean. Prod. 2017 November, 166 (10) pp. 744–755

[58] INNOMEN project, https://www.innomem.eu/

[59] OASIS project, https://project-oasis.eu/