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Sustainable Nanomanufacturing Framework

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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.

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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]