SUSNANOFAB
Grant Agreement No. 882506

Critical analysis of nanofabrication best practises and common protocols

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D3.3 Repository best practices_01	21/04/2022	Overview of the SUSNANOFAB repository with particular emphasis on the approach followed for the collection and analysis of nanofabrication best practices
D3.3 Repository best practices_02	25/05/2022	Overview of the SUSNANOFAB repository and analysis
D3.3 Repository best practices_03d	27/05/2022	Almost final version

Abbreviations and Acronyms

Acronym	Description
EPPN	European Network for Pilot Production Facilities
EMMC	European Material Modelling Council

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Project website: http://susnanofab.eu/.

Executive Summary

This deliverable describes the development of the SUSNANOFAB repository, which has two main purposes: to act as key input source for the Roadmap and the Digital Platform and to become a point of reference for EU and international best practices and common protocols, enabling sustainable nanofabrication in the target sectors (as part of the SUSNANOFAB Digital Platform). The repository is released together with this report D3.3 which provides the description of the repository assembly process (input to the SUSNANOFAB Digital platform, T.5.3 – *Enhancement of the Digital Platform),* a critical analysis of the collected best practices and recommendations for actions (input to Task 3.3 - *Roadmap for a EU wide strategy on nanofabrication*) and training (which represents a necessary input to the whole WP4).

The repository has been assembled in excel format and comprises four units:

- Projects & Initiatives
- Regulations
- Best Practices
- Standards

Each unit has a comprehensive list of items related to nanofabrication and it will represent an useful source of information for a team approaching nanofabrication activity while being useful at same time for addressing issues. The repository has been created with the input from SUSNANOFAB partners TYNDALL, IDONIAL, RINA-C, TUW, CEA, INL, ONVEGA and in consultation with the Coordination Groups.

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This work will be shared with the interested stakeholders as the repository contents will be accessible by registered users of SUSNANOFAB Platform, which, in turn, will be also able to upload information based on their personal knowledge and experience.

This report is divided in 4 sections.

Specifically, Section 1 provides an overview of the deliverable, its aims and objectives and its relationship with other deliverables and tasks within the wider SUSNANOFAB project.

Section 2 is dedicated to the best practices. It gives a definition for the term "best practice"; provides details on how to identify a best practice and what the structure/content of a best practice should be. It also highlights the importance of capturing and sharing best practices.

Section 3 gives and overview of the repository and its four units (Projects & Initiatives, Regulations; Best practices, Standards) and describes the methodology used for the acquisition of the repository data from different platforms, reference journals and databases.

Section 4 describes the critical analysis of the collected data, with particular emphasis on the best practice analysis. It includes a gap analysis, a geographical distribution of the practices and recommendations for actions and training.

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1. Best Practices: Definition and Strategic Importance

A best practice is defined as a process or methodology that through experience or research has proven reliably to lead to the desired results and can be therefore recommended as reference model.[1] Therefore, a best practice is different than a standard as the term "best practice" is not about a state of perfection. Rather, the term "best practice" refers to a successful experience which has been tested and validated in practice and demonstrate high transferability potential. Results presented in a best practice protocol may be partial but might be relevant to progress that particular research or to promote development into complementary applications. The purpose is to get inspiration and learn from others, who have already faced and successfully overcome similar challenges to facilitate progression.

It is important to capture and disseminate good practices as they are key for:

1) Building capacity.

2) Support innovation.

3) Align existing policies and practices.

4) Raising economic potential.

5) Increase efficiency (*e.g.*, by adopting tools or components of them, which have proved to work well in similar contexts).

6) Capitalise on existing knowledge.

Best practices may come from a variety of sources, including research organizations, industry, civil society organizations, community groups and individuals. Different templates can be used to collect relevant information.

[1] Osburn, Joe, Guy Caruso, and Wolf Wolfensberger. "The Concept of "Best Practice": A brief overview of its meanings, scope, uses, and shortcomings." International Journal of Disability, Development and Education 58.3 (2011): 213-222.

In the context of nanotechnology/nanofabrication/nanomaterials the aim of best practices is often to provide guidelines on potential human health and environmental concerns evaluation associated to the entire life cycle of nanomaterials used in a specific application or product, focusing on the manufacturing process if applicable. In this context, a best practice aims to allow the user of a new nanomaterial to evaluate the associated risks and to make decisions for minimising those risks. Therefore, best practices, constitute a guidance for stakeholders to proactively minimise potential concerns for any nanomaterial of interest that is under development. A wider aim of best practices is to provide tutorials/protocols/guidelines on specific methods or processes of technological interest.

The identification of best practices involves judgement, in the form of a prior analysis following a set of criteria (some more essential than others, depending on the field of application) as shown in Table 1 below:

Table 1. List of *essential criteria suggested to be used for the identification of a best practice [1].*

CRITERION	DESCRIPTION
Effectiveness	The practice must work and achieve results that are measurable
Efficiency	Production of results with a reasonable level of resources and time
Relevance	Address of priority specific problems/issues
Sustainability	Implementable over a long period with the use of existing resources
Possibility of duplication	Replicable
Involvement of partnership	Collaboration/participation between several stakeholders

The majority of best practices are characterised by a structure similar to the structure of a scientific manuscript. Specifically, they contain i) an introduction section whereby the context and justification of the practice as well as the motivation for compiling it as clearly stated; ii) an implementation of the practice follows whereby the main activities carried out are explained; iii) a methodology section describing methods used and outcomes achieved; iv) finally, a conclusion highlighting the importance and relevance of the obtained results and a reference section are reported. Importantly,

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documenting and applying lessons learned also on what has been tried and did not work and why it did not work are integral parts of a best practice, so that the same types of mistakes can be avoided by other programmes and projects. Therefore, a lesson learn section should be inserted before the conclusion paragraph.

2. SUSNANOFAB Repository

The core of the repository is a comprehensive list of best practices across different topics related to nanofabrication. However, the repository also includes three more units containing a list of relevant projects and initiatives, regulations and standards which are relevant for the purpose of tracking guidelines in the context of nanofabrication.

Overall, the repository comprises the following four units:

- Projects & Initiatives
- Regulations
- Best Practices
- Standards

The data contained in each repository unit (which initially are collected in an excel file) is related to nanofabrication and has been classified around the targeted sectors selected by the SUSNANOFAB project, specifically:

1) Health.

2) Food & Natural resources.

3) Mobility.

4) Digital industry.

5) Inclusive & secure Society.

6) Climate/Energy.

In addition, a number of cross-sectorial areas were also taken in consideration as follows: manufacturing; safe-by-design, modelling, green/sustainable approaches, nanofabrication.

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3.1 Methodology: collection of Project & Initiatives data

This section shows an overview of the projects listed in the repository (see Table 2) and how they are classified. The exhaustive list includes 79 projects which have been collected starting from those reported in D2.2. The considered projects were still actively running at the time of compilation (Dec 2021 –March 2022).[2] . Each project was classified within the appropriate sector and targeted product. Furthermore, details of project title, description, cordis link and website are also provided.

Table 2. *Snapshot overview of a set of projects listed in the repository collected from the CORDIS database.*

Sector	Target products	Projects / Initiatives	Description	Cordis	Website
Health	Nano-biosensors, smart drug delivery systems, implantable materials, wearable	**One Health EJP** (ID:773830, https://onehealthejp.eu/): Promoting One Health in Europe through joint actions on foodborne zoonoses, antimicrobial resistance and emerging microbiological hazards.	The One Health concept recognizes that the human health is tightly connected to the health of animals and the environment, i.e. that animal feed, human food, animal and human health, and environmental contamination are closely linked. The One Health EJP will also develop sustainable programs and projects beyond the lifetime of the EJP, through the production of a Strategic Research and Innovation Agenda (2021-2030) and a European P2P One Health Cooperative Joint Initiative.	CORDIS	WEBSITE
Health	Nano-biosensors, smart drug delivery systems, implantable materials, wearable	**iReceptor Plus** (ID:825821, http://www.ireceptor-plus.com): Architecture and tools for the query of antibody and t-cell receptor sequencing data repositories for enabling improved personalized medicine and immunotherapy	Project: The iReceptor Plus consortium of researchers from Europe and Canada will address several key challenges to optimally sharing AIRR-seq data among public and industrial partners: protecting patient privacy and the intellectual property of partners, performing complex analyses on data brought together from many sources, and expanding the size and number of repositories that can be integrated in the network.	CORDIS	WEBSITE
Food & Natural Resources	Food processing, food packaging, functional food development, nutraceuticals, detection of foodborne pathogens, and shelf-life extension of food	**HealthyLivestock** (ID:773436, http://healthylivestock.net/): Tackling Antimicrobial Resistance through improved livestock Health and Welfare	HealthyLivestock aims to reduce antimicrobial (AM) use by the pig and broiler industries in China and Europe, and consequent residues in meat and the environment, by improving animal health & welfare without compromising productivity.	CORDIS	WEBSITE

[2] CORDIS | European Commission (europa.eu)

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Sector	Target products	Projects / Initiatives	Description	Cordis	Website
	products, food packaging				
Mobility	Nano-sensors, nano-coatings, nano-filtration, nano-additive/reinforcers	**NEXT-GEN-CAT** (ID:280890): Development of NEXT GENeration cost efficient automotive CATalysts	The main objective of NEXTGENCAT proposal is the development of novel eco-friendly nano-structured automotive catalysts utilizing transition metal nanoparticles (Cu, Ni, Co Zn, Fe etc) that can partially or completely replace the PGMs. Based on nanotechnology, low cost nanoparticles will be incorporated into different substrates, including advanced ceramics (SiO_2, perovskite etc) and silicon carbides, for the development of efficient and inexpensive catalysts. The main idea of the proposal is the effective dispersion and the controllable size of the metal nanoparticles into the substrate that will lead to improved performance.	CORDIS	
Mobility	Nano-sensors, nano-coatings, nano-filtration, nano-additive/reinforcers	**CitySCAPE** (ID:883321): CitySCAPE: City-level Cyber-Secure Multimodal Transport Ecosystem	With the emergence of the digitization of information, ICT infrastructure and communications gave an unprecedented push towards the realization of truly interconnected passenger transport ecosystems at city-level. CitySCAPE leverages the skills and mature technology of its 15-partner consortium to systematically explore all different cybersecurity dimensions of multimodal transport. These dimensions will drive a characterization of the cyber-threats in the ICT multimodal transport, extended to the close-by power and financial sector. Innovative software tools will be introduced to estimate the threats propagation in the system.	CORDIS	

3.2 Methodology: collection of regulatory data

A list of regulations is also included which were collected from literature search and SUSNANOFAB partners' inputs. The regulation sheet includes 12 regulations, mainly related to the sectors of health and Food & Natural Resources. Table 3 shows a snapshot overview of the repository "Regulations" section. Each regulation was classified by sector and target product. Information on the origin (EU), brief description and link is also provided. Input for this section originated from research publications on "health and implantable materials", "food packaging and food development" as well as direct inputs from SUSNANOFAB partners.

Table 3. *Snapshot overview of the repository content of the regulations.*

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Sector	Target products	regulation	Description	nr	description	link
Health	Nano-biosensors, smart drug delivery systems, implantable materials, wearable	Directive	EU	2005/28/EC	principles and detailed guidelines for good clinical practice as regards investigational medicinal products for human use, as well as the requirements for authorisation of the manufacturing or importation of such products	CELEX 32005L0028
Food & Natural Resources	Food processing, food packaging, functional food development, nutraceuticals, detection of foodborne pathogens, and shelf-life extension of food products, food packaging	Directive	EU	2005/28/EC	detailed guidelines for good clinical practice as regards investigational medicinal products for human use, as well as the requirements for authorisation of the manufacturing or importation of such products.	CELEX 32005L0028
Food & Natural Resources	Food processing, food packaging, functional food development, nutraceuticals, detection of foodborne pathogens, and shelf-life extension of food products, food packaging	Regulation	EU	258/97	novel foods and novel food ingredients.	CELEX 31997R0258
Food & Natural Resources	Food processing, food packaging, functional food development, nutraceuticals, detection of foodborne pathogens, and shelf-life extension of food products, food packaging	Regulation	EU		Substances added to food for a technological purpose or to improve solubility, flavour, or bioavailability, are covered by the "Food Improvement Agent Package". It includes Regulation (EC) 1332/2008 on food enzymes (European Parliament and Council, 2008b), Regulation (EC) 1333/2008 on food additives (European Parliament and Council, 2008c) and Regulation (EC) 1334/2008 on flavourings and certain food ingredients with flavouring properties.	EUR-Lex - 32008R1333 - EN - EUR-Lex (europa.eu)

3.3 Methodology: collection of standards data

The repository contains a section with public information on existing standards and standardisation activities, elaborating from the inputs on standardisation initiatives provided in D2.2. The standard section collects the list of all standards issued from several major institutes working in the field of standardization. More specifically, we were able to collect 120 ISO standards, 78 IEC standards, 6 IEEE, and 28 ASTM standards having nanotechnologies as direct subject of those standards. For each standard, the standardization body, standard identifier, standard title, publication date, and a short description are reported altogether with a link to the document, when available, or the paywall page related to the document, when not available (see below, Table 4).

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Table 4. *Snapshot overview of the standards repository content.*

Standardization body	ID	Title	pubDate		description	link
ISO	ISO/CD 19337	Nanotechnologies - Characteristics of working suspensions of nano-objects for in vitro assays to evaluate inherent nano-object toxicity	2/15/2022	This document reached stage 30.20 on 2022-02-15, TC/SC: ISO/TC 229, ICS: 07.120	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/08/05/80583.html	ISO
ISO	ISO/PRF TS 4988	Nanotechnologies - Toxicity assessment and bioassimilation of manufactured nano-objects in suspension using the unicellular organism Tetrahymena sp.	2/15/2022	This document reached stage 50.00 on 2022-02-15, TC/SC: ISO/TC 229, ICS: 07.120	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/08/05/80595.html	ISO
ISO	ISO/TR 18196:2016	Nanotechnologies - Measurement technique matrix for the characterization of nano-objects	2/10/2022	This document reached stage 90.92 on 2022-02-10, TC/SC: ISO/TC 229, ICS: 07.120	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/17/61734.html	ISO
IEC	IEC/CD 62565-3-1	Nanomanufacturing - Material specifications - Part 3-1: Graphene - Blank detail specification	2/8/2022	This document reached stage 30.60 on 2022-02-08, TC/SC: ISO/TC 229, ICS: 07.120	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/67/66782.html	IEC
ISO	ISO/TS 21357:2022	Nanotechnologies - Evaluation of the mean size of nano-objects in liquid dispersions by static multiple light scattering (SMLS)	1/14/2022	This document reached stage 60.60 on 2022-01-14, TC/SC: ISO/TC 229, ICS: 07.120	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/07/07/70759.html	ISO
ISO	ISO/TS 12805:2011	Nanotechnologies - Materials specifications - Guidance on specifying nano-objects	12/15/2021	This document reached stage 90.93 on 2021-12-15, TC/SC: ISO/TC 229, ICS: 07.120	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/17/51766.html	ISO
ISO	ISO/TS 80004-5:2011	Nanotechnologies - Vocabulary - Part 5:	12/15/2021	This document reached stage 90.93 on 2021-12-15, TC/SC:	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data	ISO

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Standardization body	ID	Title	pubDate		description	link
		Nano/bio interface		ISO/TC 229, ICS: 07.120; 01.040.07	/standard/05/17 /51767.html	
ISO	ISO/TS 80004-2:2015	Nanotechnologies - Vocabulary - Part 2: Nano-objects	12/15/2021	This document reached stage 90.93 on 2021-12-15, TC/SC: ISO/TC 229, ICS: 07.120; 01.040.07	https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/44/54440.html	ISO

3.4 Methodology: collection of best practice data

Two parallel approaches were used for the collection of best practice.:

- The first approach was to identify scientific journals of high impact factor dedicated to the publication of methodologies, guidelines and protocols. The following journals were targeted: Nature Protocols, Nature Methods, Science Advances, Scientific Reports and Methods and Protocols. For each journal, a search was performed using key words such as "nanomaterials", "nanotechnology", "nanomanufacturing", "safe-by-design" and also "nano AND health"; "nano AND food" etc, in order to cover all target sectors (see next paragraph for a detailed list of the targeted sectors). Some of the same key words were used to search on dedicated databases such as the European Network for Pilot Production Facilities (EPPN),[3] the European Material Modelling Council (EMMC), [4] the database of MODA (Modelling Data Elements) [5], and the Nanosafety Cluster[6] in order to ensure interoperability of the SUSNANOFAB Digital Platform with other platforms.

In parallel, a talk was organised during the 3rd Coordination Group Meeting (2nd March 2022, delivered by Tyndall) aiming at explaining the concept of best practice and at encouraging the sharing of best practices available within the various

3 EPPN | European Network For Pilot Production Facilities And Innovation Hubs (eppnetwork.com)
4 MODA - Description & use cases are available now @ EMMC! | EMMC
5 Home - Publications Office of the EU (europa.eu)
6 EU NanoSafety Cluster – The NanoSafety Community

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participating expert groups. Shortly after the meeting, a survey was sent out to the expert to collect relevant information (see Annex 1).

Table 5 shows a snapshot of the assembled best practice database. As can be seen, for each best practice a sector was associated and details of title, description, reference, year of publication, author, affiliation and link were provided. The repository provides an easy association between the context/ or the issue to be addressed (also thank to the keywords included in the short description) and a source of information (typically a scientific paper) where a best practise/methodology is fully described.

Table 5. Snapshot overview of the best practices repository content.

Code	Sector	Target products	Title	Short Description	link	Year of publication	author	affiliation	DOI	Specific application
BP_HE_0001	Health	Nano-biosensors, smart drug delivery systems, implantable materials, wearable	Production of tunable nanomaterials using hierarchically assembled bacteriophages	This protocol describes how to design and produce hierarchically assembled nanomaterials with tunable functionalities using engineered M13 bacteriophages.	Nature Protocols 12, 1999–2013 (2017)	31/08/17	Ju Hun Lee et al	University of California Berkeley,	https://doi.org/10.1038/nprot.2017.085	Applicable in new devices for multiple applications
BP_IS_0001	Intersectoral	Nano-biosensors, smart drug delivery systems, implantable materials, wearable	Preparation, characterization, and in vitro dosimetry of dispersed, engineered nanomaterials	Details for dispersion and colloidal characterisation of suspended engineered nanomaterials, and computational fate and transport modelling to accurately calculate dose metrics for in vivo cellular nanotoxicology experiments	Nature Protocols 12, 355–371 (2017)	19/01/17	Glen M DeLoid et al	Center for Nanotechnology and Nanotoxicology, HSPH-NIEHS Boston, Massachusetts	https://doi.org/10.1038/nprot.2016.172	New devices for multiple applications; Mobility ,Digital Ind, Inclusive and Secure Soc., Health

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Code	Sector	Target products	Title	Short Description	link	Year of publication	author	affiliation	DOI
BP_HE_0003	Health	Nano-biosensors, smart drug delivery systems, implantable materials, wearable	Bioconjugates of photon-upconversion nanoparticles for cancer biomarker detection and imaging	synthesis, biofunctionalization and purification of lanthanide-doped photon-upconversion nanoparticles and describe their application in both immunoassays for sensitive detection of blood-based biomarkers and bioimaging of cancer cells.	Nature Protocols 17, 1-45 (2022)	18/02/22	Antonin Hlavacek et al	Institute of Analytical Chemistry of the Czech Academy of Sciences, Brno; Masaryk University,	https://doi.org/10.1038/s41596-021-00670-7
BP_CE_0001	Climate/energy	Solar PV; catalysis, batteries & supercapacitors; hydrogen fuel cells	Enhanced efficiency in hollow core electro spun nanofiber-based organic solar cells	High-efficiency bulk heterojunction (BHJ) solar cells have been obtained by introducing hollow core polyaniline (PANI) nanofibers as a buffer layer. An improved power conversion efficiency in polymer solar cells (PSCs) was demonstrated through the incorporation of electro-spun hollow core PANI nanofibers positioned between the active layer and the electrode. Keywords: heterojunction, PANI, nanofibers	Scientific Reports volume 11, Article number: 21144 (2021	27-ott-21	Filippo Pierini	National Clinical Research Center for Oral Diseases, gy, Sichuan University, Chengdu, P.R China	https://doi.org/10.1038/s41596-020-0355-z
BP_HE_0011	Health	Nano-biosensors, smart drug delivery systems, implantable materials, wearable	Using nanoneedles for intracellular delivery	how to develop a nano injection workflow, including the selection of nanoneedle devices, approaches to loading cargo, strategies for interfacing to biological systems and assays to evaluate the efficacy of intracellular delivery. Keywords: nanoneedles fabrication, nanoneedle interfacing, nano-injection	Nature Protocols 16, 4539–4563 (2021)	23/08/21	Ciro Chiappini et al	King's College London, London, UK;	https://doi.org/10.1038/s41596-021-00600-7

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Best practises repository list will be continuously increased thanks to the SUSNANOFAB Digital Platform which will include a form for Best Practise collection from the registered users (see Figure 1).

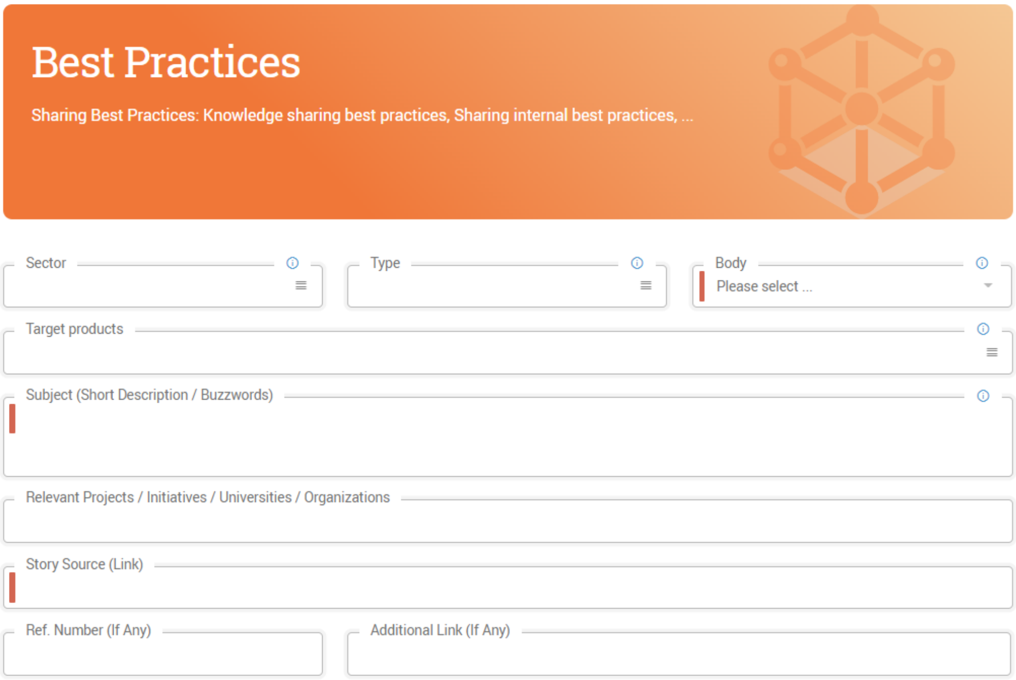

Figure 1 *Best Practice Form (Collection feature of SUSNANOFAB Digital Platform).*

The initial target of the SUSNANOFAB project was to gather at least 30 best practices. However, as it will be evident from the repository, the number of practices captured largely exceed the original estimation.

As an example, a full description of the best practice BP_HE_0011 is reported below.

Code	Full description
BP_HE_0003	Detailed steps for six common nanoneedle fabrication methods are included in the information source. The corresponding six nanoneedles are the following: a) nanowires, b) solid nanopillars, c) nanotubes, d) porous nanopillars, e) porous nanocones, f) nanostraws Best practises for fabrication: a) During Chemical Vapor Deposition (CVD) tuning temperature and silane gas flow can control the key geometric aspects required for efficient nano-injection. b) Metal deposition via photolithographic masks followed by lift-off forms an array of disks for desired nanopillar geometry c) Nanorings with controlled inner and outer diameters via EBL followed by DRIE can produce nanotubes.

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	d),e) using Metal-Assisted Chemical Etching (MACE), which generates high-aspect-ratio pSi nanostructures in a single step, produces nanocones and nanopillars with tunable porosity, with the advantage of simpler manufacturing, a satisfactory cost-efficient synthesis path and high throughput f) performing atomic layer deposition (ALD) of materials on a track-etched membrane template can manufacture nanostraws with a good degree of control over the key geometric aspects of these nanoneedles.

3. Analysis and recommendations for actions

4.1 Best Practice Analysis

This section contains a statistical analysis of practices per sector and identified sector gaps. A total of 101 best practices are included in the repository. Their distribution per sector is shown in Figure 1 whereas their percentage distribution is shown in Figure 2.

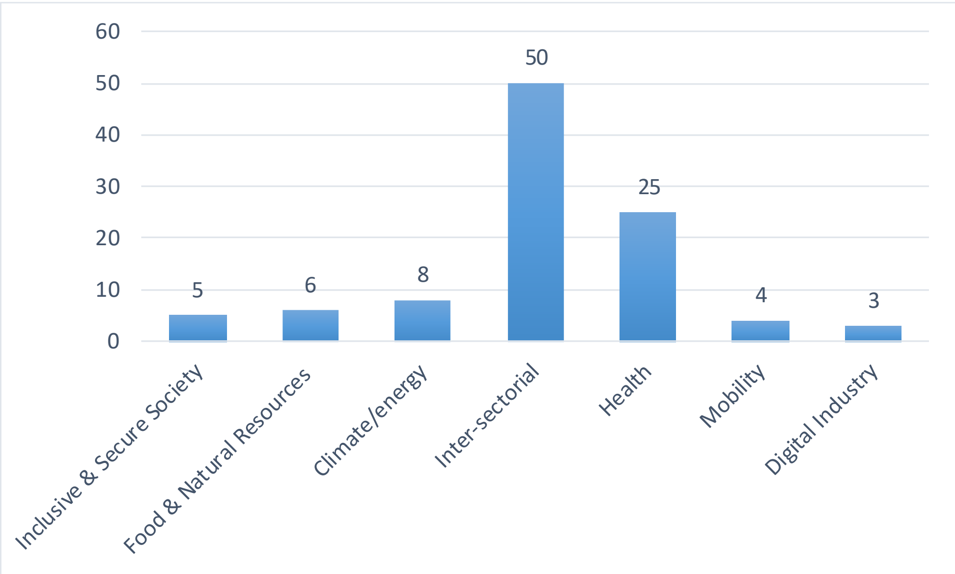
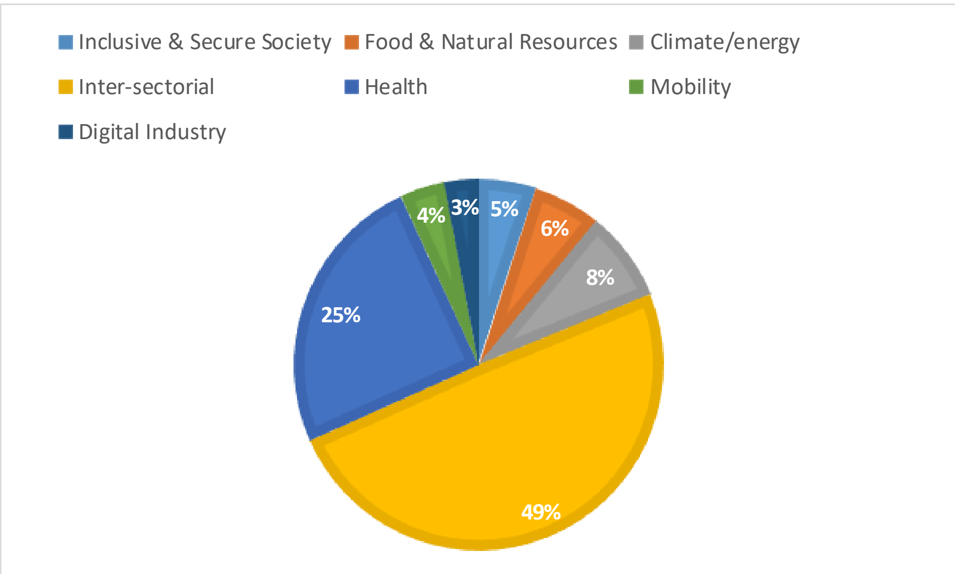


Figure 2 *Distribution of best practices per sector*



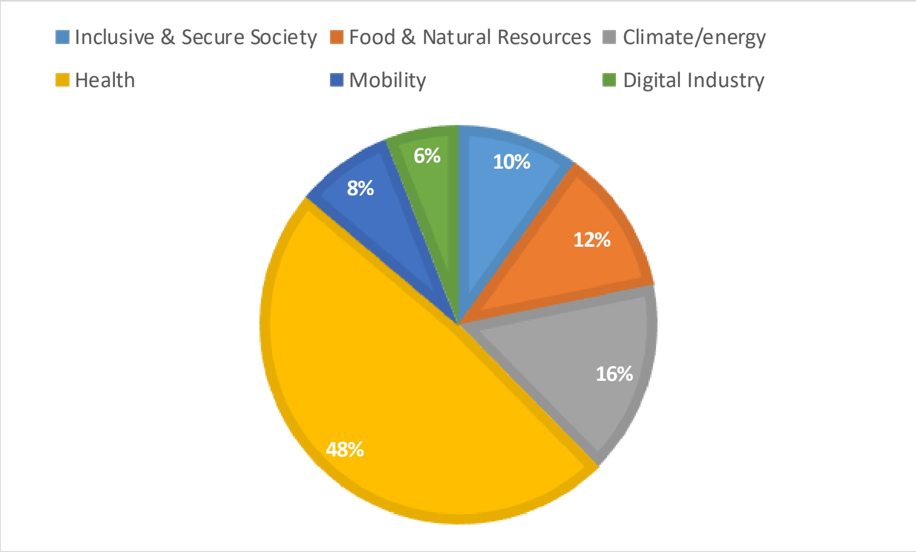


Figure 3 *Top: Percentage distribution of best practices per sector, including intersectoral practices. Bottom: Percentage distribution of best practices per sector, excluding inter-sectorial practices*

Main emerged points per sector: the **health** sector was the most populated sector with 48% of found best practices across different sub-topics such as drug delivery, biosensors and implantable devices. This might be related to the high level of regulation already present in this sector, due to the obvious human applications. In fact, the health was also the sector where the highest number of regulations were found (see repository). The Climate/energy and Food & Natural Resources sectors were found to occupy most of the remaining distribution, with a combined 28% percentage. According to the Regulations unit of the repository the **Food & Natural resources** sector was quite regulated, due to the obvious human dimension. However, as new nanomaterials are being incorporated into products in fields such as of nutraceuticals, food packaging and food processing, more research and best practices need to be developed to ensure the safe use of such products. Most of the best practices related to the **Climate/Energy** sector were in the fields of energy storage (batteries, supercapacitors and development of related materials and processes). This sector is expected to grow as the demand for alternative energy storage, catalysis and photovoltaic solutions increases. Less number of best practices were found for the remaining sectors. However, it should be mentioned that some of

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the best practices catalogued in the inter sectorial units (especially in Manufacturing and Nanofabrication) could also have had a double location.

The inter-sectorial sectors were further divided as follows: Nanofabrication, Manufacturing, Green/sustainable approaches, Safe-by-design and Modelling. The distribution of these sectors is shown in Figure ~~3~~4.

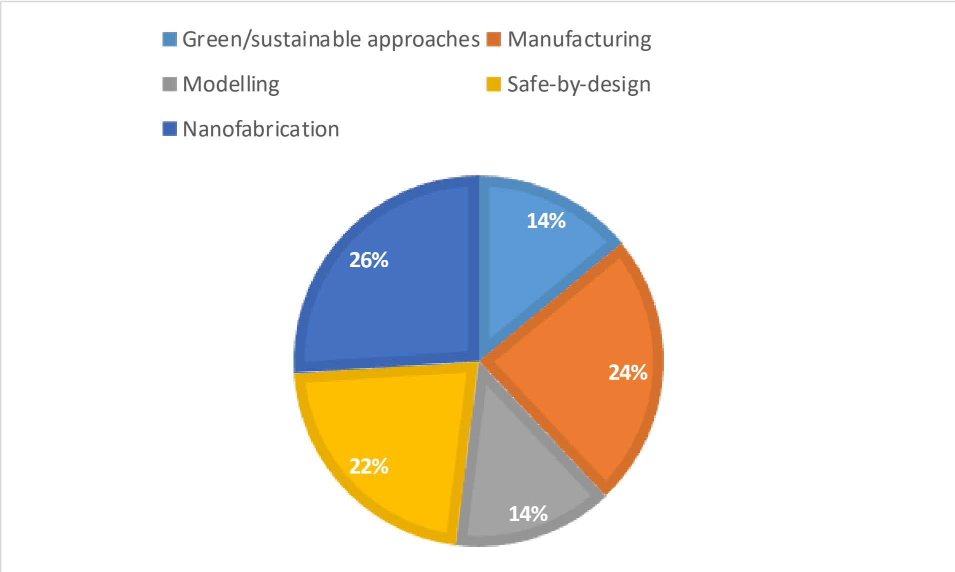

Figure 4 *Percentage distribution of intersectoral best practices.*

As expected, the fields of Nanofabrication and Manufacturing were the largest, as they comprise processes related the production of materials and products for multiple sectors. Safe-by-design practices emerged as key support for the future development of safe-to-use (both for the environment and for humans) products and to promote societal acceptance of nano-enabled products. As well as "safe-by-design" best practices, a new trend has emerged, related to the use of green materials and processes for the manufacturing of novel "green" nanomaterials and nano-devices. This trend has been driven by the environmental concern associated to the ubiquitous development of sensors/wearable sensors and IoT devices, which demands adoption of novel green process to ensure sustainability. However, in parallel, the suitability of naturally sourced materials in terms of low human and environmental toxicity needs to be established. Furthermore, the technical performance of these materials need to be

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assessed and benchmarked against their not sustainable counterpart in order to ensure suitability of specific applications.

4.2 Geographical distribution of best practises

Figure 5 shows the geographical distribution of best practices around the continent. The attribution was made considering the affiliation of the best practice corresponding authors, which is an approximation, as many best practices were generated through the contribution of multiple research associations across different continents. However, even considering such approximation, it was interesting to see that Europe, North America and Asia contributed almost equally, taking 97% of all contributions.

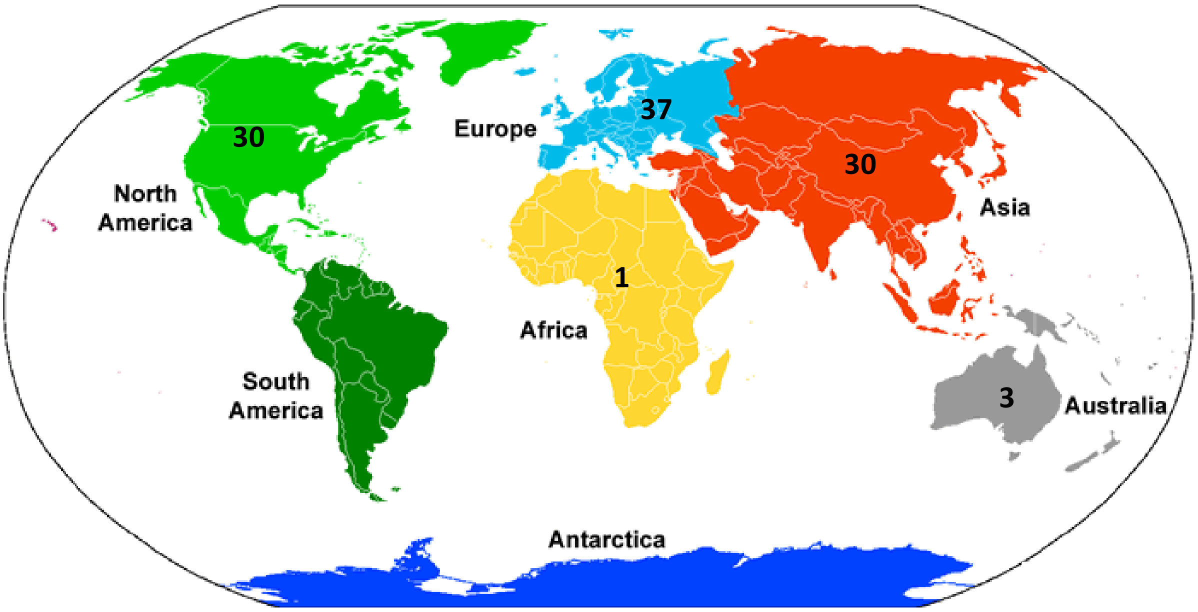

Figure 5 *Geographical distribution of best practices by continent.*

A closer look into the European landscape revealed that the UK and Germany contributed most to the generation of best practices, followed by Spain (Figure 6). This finding may be due to a high number of centres specialized in safe by design and sustainable approaches inter-sectoral sectors.

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Figure 6 *Geographical distribution of best practices within Europe.*

4.3 Recommendations for training

From the analysis of data collected in the repository the following knowledge gaps were identified, which could be addressed by training.

- Clear and unified methodologies for the risk assessment of nanomaterials and nano-enabled products.
- Competences and trainings mixing Life Cycle Analysis approach together with risk management.
- Trainings on the creation of specific standards to answer the need of standardization for novel technologies.
- Unified methodologies and training for the "green-by-design" fabrication of nanomaterials and nano-based products.
- Trainings and competencies and unified methodologies for recycling of nano-based products.

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- Training on how to deploy a proper governance structure to quickly and smoothly adapt to regulation changes. Competencies on how to think ahead safety and regulation as a risk governance.
- Very specific trainings on modelling tools as answers to performance prediction and safety.
- Competences in modelling to be able to grasp the potential given by nanofabrication technologies when it comes to safety and performances of novel products.

4. Conclusions and recommendations for action

In conclusion, the analysis of best practices revealed that the most populated sector was Health. However, a large percentage of best practices was taken by the intersectoral topics, of which Nanofabrication and Manufacturing were the most populated. Safety issues, captured in the intersectoral unit "Safe-by-design" were high in presence, highlighting the need for unified approaches in order to promote upscaling and sustainability. The substitution of "traditional" nanomaterials and fabrication techniques with greener solutions, captured in the "Green/Sustainable approaches", is gaining popularity and it is deemed necessary for the sustainability of all sectors.

The collected best practices will be accessible to interested users by accessing the SUSTNANOFAB platform, upon registration. In addition, the repository will be continuously fed by the contribution of users that will be able to share their knowledge, concerning detailed best practices for nanofabrication.