A common European approach to the regulatory testing of nanomaterials

NANoREG

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1 Description of task

According to the DoW, this first task would identify and map the critical exposure scenarios (in terms of economic importance and regulatory gaps) across the three domains, consider the data gaps and develop a program of data collection (measurement) to fill these data gaps (Task 3.3). This Deliverable includes the identification and mapping of critical exposure scenarios and lists of data gaps that can altogether be used to define the program of data collection. The latter is not defined at this point, as it also depends on technical and expertise constrains, and not all partners in Task 3.3 are part of Task 3.1.

2 Description of work & main achievements

2.1 Summary

This Deliverable aimed at identifying data gaps and prioritizing exposure scenarios of potential highest exposure along the value chain of currently marketed ENM. To reach this goal, an extensive evaluation of the state of the art for the core set of nanoparticles selected for the NANoREG project was performed, considering factors such as volume of European production, main market applications of ENM used in nano-enabled products, existing exposure data and previously reported data gaps. Thereafter, use maps were developed for the main applications for the core set of ENM selected in the NANoREG project. Finally, use descriptors and exposure determinants were collected for each exposure scenario in the use maps, and these scenarios were ranked using the scores obtained from exposure ranking algorithms. The gaps identified during this process and the ranking of exposure scenarios can be used to define the experimental work in the remaining tasks of WP3.

2.2 Background of the task

The main aim of Deliverable 3.1 is to identify critical exposure scenarios (in terms of potential exposure and economic importance) and map them across the three domains: occupational, consumer and environment. The identified critical exposure scenarios, and the data gaps in such scenarios, can then be used to define a programme of data collection, i.e. measurements that will be carried out throughout the tasks 3.2 and 3.3.

Some of the regulatory questions within NANoREG that are relevant to WP3 (Table 1), were addressed by evaluating the state of the art regarding exposure data. Some determinants for occupational, consumer and environmental exposure were identified and used for exposure scenario prioritization in this task. However, these lists should not be considered complete or adequate for other purposes. Tasks 3.2 to 3.5 will generate information to further address the regulatory questions.

Table 1. Regulatory questions addressed in WP3

Exposure: What are the main determinants for occupational and consumer exposure to ENM and what are the duration and type of exposure?
Exposure: How should human and environmental exposure be assessed in practice?
Exposure and life cycle analysis: Which scenarios could denote potential exposure and what information do we have on them? Can we develop standardized and efficient testing procedures for estimating release of ENM from powders and ENM in matrices? Which are the situations in which ENM exposure is expected to be negligible/ high? Are the amount and nature of releases of ENM similar to regular chemicals, when common recycling and end-of-pipe techniques are used? How to minimize and structure LCA to avoid ending up with a 1:1 model of the world?

2.3 Description of the work carried out.

In order to meet the objectives of the task, the approach depicted in Figure 1 and described below was followed.

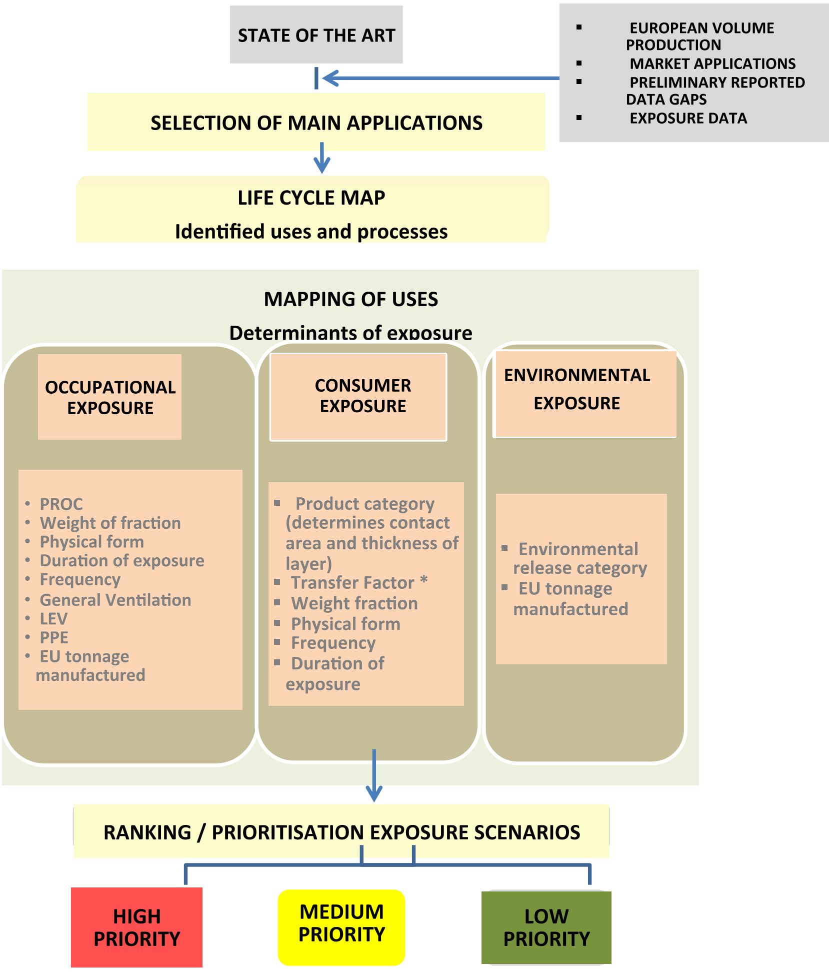
- ✓ Extensive evaluation of the state of the art for the core set of nanoparticles selected for the NANoREG project, considering factors such as volume of European production, main market applications of ENM used in nano-enabled products, and existing exposure data. Data has been obtained by AIDICO, ITENE and LEITAT partners, from literature review and from on-going and/or concluded scientific projects. The analysis of the state of the art is presented in Section 2 of this Deliverable.

- ✓ Mapping the uses of the core set of ENM selected in the NANoREG project. This consisted in mapping the known downstream and consumer uses, employing the standard terminology of the descriptor system assigned to all life cycle stages. Each partner involved in the task gathered data on ENM based on their expertise and involvement in other research projects. The mapping of uses is presented in Section 3 of this Deliverable.

- ✓ Development of exposure scenarios compiling information on use descriptors, material characteristics, operational conditions, and risk management measures (section 4.1 of this Deliverable).

- ✓ Definition of algorithms for estimating exposure, based on the exposure determinants included in the exposure scenarios. Accordingly, priorization of exposure scenarios has been carried out (section2.5.2).

Figure 1. Approach for ranking/prioritising Exposure Scenarios.



**Note: Determinants of consumer exposure were collected, but very limited data for transfer factor are available, and due to the weight of this exposure determinant, consumer exposure scenarios were finally not taken forward for prioritization.*

2.4 Results

2.4.1 State of the art

The main goal of the state of the art review is to gather information on production volumes, applications and exposure data on the selected engineered nanomaterials (ENM). The information on production volumes is later used in this deliverable to identify scenarios that can lead to the highest releases to the environment and that can affect the largest number of workers. The information on applications is used to develop the mapping of uses for each ENM and to define relevant exposure scenarios.

As part of this section, previously reported data gaps regarding exposure to NM have been collected.

2.4.1.1 European production volumes

Engineered nanomaterials (ENM) cover a heterogeneous range of materials. In terms of market volume the main categories include inorganic non-metallic (e.g. synthetic amorphous silica, aluminium oxide, titanium dioxide), carbon based (e.g. carbon black, carbon nanotubes), metal (e.g. nanosilver) and organic nanomaterials which include among others, macromolecular or polymeric particulate materials (e.g. dendrimers). ENM often exist in a variety of forms and may be tailored for individual properties or uses (European Comission, 2012).

Not much is currently known about the quantitiesof ENM that are produced in Europe even though but this information is crucial for environmental exposure assessment. It is striking that there is a lack of information about effective quantities of ENM in circulation (Hendren, Mesnard, Dröge, & Wiesner, 2011) For most of the ENM only few and sometimes conflicting data about production amounts are available, and this lack of information presents one of the major obstacles in assessing possible risks to the environment (Gottschalk & Nowack, 2011).

In this regard, any estimates of the market size need to be taken with a certain degree of caution, although the general patterns of the estimates (i.e. order of magnitude of tonnage and market value, and relative size of market between the various materials) seem to be rather reliable. According to market data from SRI International, the global quantity of engineered nanomaterials marketed annually is around 11.5 million tonnes, with a market value of roughly 20 bn €. The market is dominated by two very widespread commodity materials, i.e. carbon black (9.6 million t), and synthethic amorphous silica (1.5 million t). Other nanomaterials with significant amounts on the market include aluminium oxide (200 000 t), barium titanate (15 000 t), titanium dioxide (10 000 t), cerium oxide (10 000 t), and zinc oxide (8 000 t). The global market for nano-TiO_2 is estimated to be about 10 thousand tonnes per year. The European Commission has also received estimates which are higher than this but still in the same order of magnitude. Around five thousand tonnes per year are used in the personal care industry, of which around 430 tonnes in sunscreens. With respect to zinc oxide, its global market is approximately estimated in several thousand tonnes per year.

Carbon nanotubes and carbon nanofibres are currently marketed at annual quantities of several hundreds of tonnes (other estimates go up to a few thousands of tonnes). The market of carbon nanotubes (thinner than 20 nm) worldwide is estimated around 200-250 tonnes (€30-40 million, mostly multi-walled carbon nanotubes) in 2009. According to SRI, the market for carbon nanofibres in the thickness range between 20 to several 100 nm is estimated at around 300-350 tonnes (€50-60 million) in 2009. There are also significantly higher estimates in terms of marketed volumes of carbon nanotubes, nanofibers and fullerenes (around 3500 tonnes annually). Nanosilver is estimated to be marketed in annual quantities of around 22 tonnes (around 10% as antimicrobial agent). With regard to nanocellulose, despite being the most available natural polymer on earth, it is only recently that has gained prominence as a nanostructured material, in the form of cellulose nanocrystals (CNC) and micro/nanofibrillar cellulose (MFC/NFC). According to Research & Markets, there are now a number of producers, from small and medium entreprisers to multi-national companies, and production volumes will increase to over 300 tons per annum over the next year and over 3000 tons per annum by 2016 (The Freedonia Group, 2012). In addition to that, there is a wide variety of nanomaterials which are either still at the research and development stage, or which are marketed only in small quantities, mostly for technical and biomedical applications.

Table 2 summarizes the global market estimation of different nanomaterials.

Table 2. Global market estimation (European Comission, 2012).

NANOMATERIAL	Volume	Estimated value
Carbon Black	9.5 million of tonnes	NA
SiO_2	1.5 million of tonnes	2.7 bn€
Al_2O_3	200 thousand tonnes	NA
$BaTiO_3$	15 thousand tonnes	NA
TiO_2	10 thousand tonnes	NA
ZnO	Several thousand tonnes	NA
CeO_2	10 thousand tonnes	NA
Ag	22 tonnes	NA
Carbon Nanotubes	200-250 tonnes	30-40 million€
Nanocellulose	300 tonnes	NA
Total nanomaterial	11.5 million of tonnes	20 bn€

N.A.: Not Available

In a review published in 2012 Piccinno et al. from the Swiss Federal Laboratories for Materials Science and Technology (Piccinno, Gottschalk, Seeger, & Nowack, 2012), presented the results based on a survey sent to companies producing and using ENM. The study focused on the actual production quantities and not the production capacities. The results reveal that some ENM are produced in Europe in small amounts (less than 10 t/year for Ag nanoparticles, quantum dots and fullerenes). The most produced ENM is TiO_2 with up to 10.000 t of worldwide production. Other authors speak of a total production of TiO_2 of 5 million tons of produced TiO_2 of which only 47,000 t are nano-TiO_2 (Keller, Mcferran, Lazareva, & Suh, 2013). CeO_2, Fe_xO_y, AlO_x, ZnO, and CNT are produced between 100 and 1000 t/year. The data for SiO_2 cover the whole range from less than 10 to more than 10,000 t/year, which is indicative of problems related to the definition of this material (e.g. whether pyrogenic silica is considered an ENM or not).

Only three refereed publications describing the method by which data were obtained are currently available (Hendren et al., 2011; Robichaud, Uyar, Darby, Zucker, & Wiesner, 2009; Schmid & Riediker, 2008). Schmid and Riediker (2008) report results from a targeted survey of Swiss companies of usage of seven ENM in Swiss industry and Robichaud et al. (2009) calculated the US production of nano-TiO_2 assuming that a certain proportion of the total TiO_2 production is in nanoform. They estimated that at the time of their evaluation about 2.5% of the total TiO_2 production of 2.5 million tons was nanoparticulate. Hendren et al. (2011) estimated upper and lower bound production quantities for five ENM in the US. A variety of sources (web sites, patents and direct communications) was used to identify companies producing ENM and to determine the production volumes. Ranges of production quantities were estimated using assumptions to attribute production amounts from companies with more reliable data to companies with little to no data.

Piccinno et al. (2012) focused their investigation on Europe but also aimed to obtain data on worldwide production and use. They sent a survey to experts in various companies and institutions within the nanomaterial industry sector and to industrial representatives from companies producing or using ENM. The main hypothesis of their work was that companies possess knowledge not only on their own production amount but also have an idea about the size of the market and that they are more likely to communicate this estimate than their own production amount. The survey comprised an inquiry about the estimates of global, national, and regional production and utilization quantities of ENM as well as the allocation of this production to different product categories. Table 3 provides estimates of production quantities (median, 25 and 75 percentiles) for the world and for Europe.

Table 3. World and Europe range of production amounts (Piccinno et al., 2012).

ENM	Worldwide (t/year)	Europe (t/year)	US (t/year) (Hendren et al., 2011)	Switzerland (t/year) (Schmid & Riediker, 2008)
	Median and 25/75 percentile	Median and 25/75 percentile	Range	In brackets values extrapolated to Europe
TiO_2	3,000 (550–5.500)	550 (55–3.000)	7.800–38.000	435 (38.000)
ZnO	550 (55–550)	55 (5.5–28.000)		70 (6.100)
SiO_2	5,500 (55–55.000)	5,500 (55–55.000)		75 (6.500)
AlO_x	55 (55–5.500)	550 (0.55–500)		0.005 (0.4)
CeO_x	55 (5.5–550)	55 (0.55–2.800)	35–700	
CNT	300 (55–550)	550 (180–550)	55–1,101	1 (87)
Ag	55 (5.5–550)	5.5 (0.6–55)	2.8–20	3.1 (270)

It is evident that especially nano-SiO_2 as well as nano-TiO_2 shows a very wide range in estimated production amounts. This means that responses were given from the low to the very high end. It is not a coincidence that these two materials have already been produced for decades now, a long time before the word ‘‘nanoparticle’’ was even invented.

Hendren et al. (2011) presented a study of the nano-TiO_2 production based on a review of information from nano-TiO_2 production patents, academic publications, and company interviews to estimate current nano-TiO_2 production volumes. One source of uncertainty in estimating this value is the proprietary nature of these emerging technologies. Current nano-TiO_2 production was estimated by applying available production data across all known producers. The maximum potential nano-TiO_2 production was then determined based on information culled from United States Geological Survey (USGS) reports and company interviews.

A methodology developed in previous studies to predict trends in conversion of the biotech industry from traditional to newer technologies was applied to estimate the rate of change in nano-TiO_2 commercialization over time (Darby & Zucker, 2001). In another work, the nano-TiO_2 production was estimated by summing the production amounts over time, as the nanoscale share of the TiO_2 market grows. It is important to note that these values are based on the nano-TiO_2 production stage of the life cycle; this method differs from some other recent exposure estimates in the literature in that the authors do not estimate nanomaterial release from products into which they are incorporated (Mueller & Nowack, 2008).

The nano-TiO_2 production estimated for nanomaterials were inherently uncertain due to the rapid evolution of the industry and proprietary nature of processes used at this early stage. At least seven companies were known in 2008 to be actively producing nano-TiO_2; however, the production volumes were typically guarded as proprietary information. The only nano production data being incorporated into the titanium dioxide mineral reports of the USGS is from DuPont, the only established bulk TiO_2 producer also producing at the nanoscale, as it is presumably included in its reported bulk volumes. DuPont produces nano-TiO_2 using an undisclosed plasma process acquired from Nanosource Technologies (Oklahoma City, OK); Nanophase (Romeoville, IL) uses physical vapor synthesis; NanoGram (Milpitas, CA) uses laser pyrolysis; Advanced Nanotech (New York, NY) uses mechanical milling; the German company Nanogate (Göttelborn, Germany) uses a sol-gel process; and Degussa (Evonik) uses yet another proprietary process. Altairnano uses a hydrochloride process with additional control steps such as spray hydrolysis, calcining, and milling to control the TiO_2 crystal size. As its patent was released in a detailed paper wherein production capacities were reported (Verhulst, Sabacky, Spitler, & Prochazka, 2003), the Altair process provides the most detailed information of all nano producers, and forms the basis of their nano-TiO_2 projections.

Figure 2. Worldwide Ti ore sources and TiO_2 production by process (reproduced from (Robichaud et al., 2009)).

Of particular relevance to nano-TiO_2 is the Vietnam production, where a plant has recently been built using the Altairnano licensed process. Its maximum capacity of 5.000-10.000 annual metric tons represents the majority of the global nano-TiO_2 capacity.

Varner et al. also estimated TiO_2 production and consumption volumes (Varner, Rindfusz, Gaglione, & Viveiros, 2010). This review assumes ultrafine TiO_2 exclusively includes nano-TiO_2 (both nanoscale and nanostructured). Similarly, it assumes that both the global and domestic production and consumption volumes of nano-TiO_2 are 0.25 percent of the global and domestic production and consumption of total TiO_2. Table 4 provides a summary of these estimates.

Table 4. Estimated Annual Volumes of Nano-TiO_2 Globally and in the United States

SOURCE	TOTAL TiO_2 (Reported)			Nano- TiO_2 (Estimated)		
	Global production (tonne/year)	U.S. Production (tonne/year)	U.S. Consumption (tonne/year)	Global Production (tonne/year)	U.S. Production (tonne/year)	U.S. Consumption (tonne/year)
USGS (2007 values)	N/A	1,450,000	1,110,000	N/A	3,630	2,780
DuPont	5,000,000	N/A	N/A	12,500	N/A	N/A

N/A: Not applicable – the value was not provided in the given source.

The total TiO_2 production levels in Table 5 are similar to those presented by Robichaud et al., who cite a global total TiO_2 annual production volume of 4 million metric tonnes and a U.S. total TiO_2 annual production volume of 1.3 million metric tonnes in 2006 (Robichaud et al., 2009). However, Robichaud et al. estimate a U.S. nano-TiO_2 production volume of 3.000 metric tonnes in 2002 and an increase to 44.400

metric tonnes in 2009. The U.S. nano-TiO_2 results in Table 5 estimate a 2007 production volume that is only 21 percent higher than Robichaud et al. 2002 estimate, whereas Robichaud et al., estimate an increase in 2009 of 1.380 percent from the 2002 estimate.

2.4.1.2 Analysis of the market applications

Engineered nanomaterials (ENM), compared to bulk materials, behave differently even though possessing the same molecular composition. ENM can provide a vast range of functions having a great potential for providing benefits to consumer products (lighter, stronger, cleaner, less expensive, more efficient, more precise or more aesthetic). This is largely due to the different material properties at the nanoscale compared to materials in the bulk form.

According to the European Comission, approximately 11.5 millions tonnes of ENM with a market value of 20 bn €, are produced and placed on the global market annually (European Commission, web). Moreover, the market for consumer products containing nanomaterials is rapidly increasing worldwide. According to the (US) Woodrow Wilson database (http://www.nanotechproject.org/cpi), which has been updated very recently, the number of consumer products that are claimed to contain nanomaterials has increased from 54 products in 2005 to 1628 products in 2013. It is expected that this increase will further continue in the near future. However, these data should be used with caution since it is possible that products on the market with the claim of “nano” may neither contain nanomaterials nor be produced with nanotechnology. On the other hand, products may not carry information on the presence of nanomaterials as there is currenty no legal obligation to lable products containing nanomaterials.

The main applications for the core ENM selected in the NANoREG project are summarized below. In addition to these ENM, data for aluminium oxide (Al_2O_3), calcium carbonate ($CaCO_3$), and nanoclay are included in this section. These ENM are not within the core list of the project but were considered of possible relevance. However, due to the lack of data on production volumes per application, they were finally considered of low priority and not taken forward in the remaining sections of this Deliverable.

Titanium dioxide (TiO_2)

Titanium dioxide powder exists both in bulk and nanoform, as well as in various crystalline phases, including rutile and anatase as the most important crystalline polymporphs. Thermodinamically, it is well recognized that rutile is the most stable crystalline phase of TiO_2 at all temperatures, while anatase is usually more active than rutile for photocatalysis. The great versatility of titanium dioxide is owing to its various forms and sizes. Titanium dioxides may be used in the form of microscale pigments or as nano-objects. In its bulk form, it has been used extensively for about 90 years as the principal white pigment (maximum reflectivity at around a particle size of 300 nanometres), due to its high reffraction index, strong light scattering and incident-light reflection capability (Table 6). Moreover, titanium dioxide is also an effective UV filter. Since dispersion of TiO_2 nanoparticles could be transparent, depending on the solid concentration, these ENM provide an aesthetic advantage for uses in sunscreens (mostly rutile). As mentioned above, anatase crystalline phase has specific electrical and photocatalytic activity under UV light, as well as antimicrobial properties (Diebold, 2003). The photocatalytic activity increases considerably because the high surface-to-volume ratio of the nanoparticles as compared to that of microparticles. In the presence of UV radiation, anatase TiO_2 can form radicals from air or water which can oxidize and remove organic pollutants.

These white pigments are not only found in paints and dyes but also in varnishes, plastics, paper, and textiles. They are used as food additives and occur in toothpastes, several other cosmetics, and drugs (as E171). TiO_2 pigments for use in plastics constitute the fastest growing market, and this is the main driver for increased production of titanium dioxide pigments. Nanoscale TiO_2 that is manufactured for specific applications is by approximately a factor of 100 finer than the TiO_2 pigments and has other physical properties. In this regard, the production volume of nanoscale TiO_2 amounts corresponds to less than 1 percent that of TiO_2 pigments. The German Cosmetic, Toiletry, Perfumery and Detergent Association (*Industrieverband Körperpflege und Waschmittel e.V. - IKW*) reported that only nanoscale titanium dioxides are presently used in sunscreens (Institute of Technology Assessment of the Austrian Academy of Sciences, 2010). To achieve better dispersion properties and ensure photostability, the TiO_2 is coated with other materials (Scientific Committee on Consumer Products, 2007).

Due to the hydrophilic character of titanium dioxide, water forms a closed film on the surface in which pollutants and degradation products can be easily carried away. House paints or tiles containing TiO_2 particles thus are self-cleaning and pollutant-degrading. Besides, so-called anti-fog coatings benefit from the hydrophilic properties of nanoscale titanium dioxide. The ultra-thin water film on a glass pane coated with a transparent layer of nanoscale TiO_2 impedes the formation of water droplets and, thus, avoids fogging. Nanoscale titanium dioxides are also suited for use in dye-sensitized solar cells (Grätzel cells).

Table 5. Main application for TiO_2 nanoparticles (Piccinno et al., 2012).

Main applications	% of total use
- Cosmetic (incl. suncreens)	70-80
- Coatings & cleaning agents	< 20
- Plastic	< 20
- Paint	10 - 30
- Cement	1
- Others	< 10

Zinc oxide (ZnO)

Zinc oxide has a very broad and versatile range of application including electronic products, cosmetics, and pharmaceutical uses. Its nanoform is colourless and an effective UV-filter with a different spectrum than titanium dioxide. It also has antimicrobial properties (though less strong than TiO_2) and can be used as an active agent in self-cleaning products.

At present, one of the main useage of zinc oxide is in the tyre manufacturing industry as additive to promote the vulcanization process ofthe rubber. In addition, its good conductivity improves the removal of heat that is generated during the churning motion of the tyres. Zinc dust and “zinc white” are also used as pore fillers in surfaces and smoothing cements and as grey or white wall or artist’s paints.

Zinc oxide is used as catalyst in the chemical industry, and also used by the pharmaceutical industry for manufacturing zinc ointments, zinc pastes, adhesive tapes, and bandages for skin and wound treatment.

Various electronic components, such as piezo-electric converters, transparent conducting oxides, sensors, luminous diodes, and optoelectronic or spintronic components, are barely conceivable without zinc oxide at present. Moreover, zinc oxide-based semiconductors are used as transparent conductive layers in blue light-emitting diodes, liquid-crystal screens, varistors, and thin-film solar cells.

Specifically, zinc oxide nanoparticles are transparent in the visible range of the light spectrum and act as a physical filter against the UV-B and particularly UV-A radiation, since ZnO adsorb these ultraviolet radiations. ZnO based filters are mainly used in sunscreens with sun protection factors above 25. Unlike chemical UV filters that may trigger allergization, physical filters are suited for application to the sensitive skin of children and allergic persons.

Zinc oxide nanoparticles are also used in textiles, in wood products and furniture as clear varnishes and in transparent plastics and plastic films (plastic glasses). Plastics containing ZnO nanoparticles are generally characterized by a high transparency in the visible spectral range (> 90 % transmission) and UV permeability for wavelengths below 360 nm (< 10 % transmission).

Table 6. Main application for ZnO nanoparticles (Piccinno et al., 2012).

Main applications	% of total use
- Cosmetic (incl. suscreens)	70
- Paint	30

Silicon dioxide (SiO_2)

There are various forms of synthetic amorphous silica placed on the market, including precipitated silica, silica gel, silica sols and fumed or pyrogenic silica.

Precipitated silica is made up of primary particles in the size range of around 5-100 nm which are aggregated and agglomerated in the final product. The biggest use of precipitated silica is for the reinforcement of elastomer products, primarily automotive tyres, footwear, rubber articles and cable sheathing. Nano-SiO_2 is used increasingly for tyre manufacturing. Adding amorphous SiO_2 as fillers in addition to carbon black in tyres, the tyre roll resistance is reduced, improve traction under slippery conditions and improve fuel efficiency. Precipitated silica is also used in batteries, as antiblocking agent in thermoplastic films, as carrier silica for liquids and semi-liquids and anti-caking agent in food powders (E551), in health care products such as toothpastes, detergents and cosmetics, as matting agents in paints and varnishes, in the paper industry as advanced fillers in newsprint paper and in special coated papers, for inkjet and direct thermal printing to enhance ink absorption and in agricultural products.

Synthetic silica gels are obtained from the polymerisation process of fine colloidal silica. They have a similar structure as precipitated silica, but the cross-linked silica particle networks form a nanopore structure that is finer than the pore structure of the aggregated particles in precipitated silica. Silica gels are sold in various types of gels (hydrogel, aerogel, xerogel, etc.). They are used in many food and health products (e.g. to selectively remove certain proteins and polyphenols that precipitate upon chilling). They are used in food industry as an anticaking agent (E551) and as a carrier for vitamins and as a tableting aid in pharmaceuticals. They can be added to certain powdery foods such as table salt, seasonings, dietary supplements, and dry foods to avoid clogging. Moreover, they are permitted for use as carrier substances in emulsifying agents, colorings, and flavors. They are also used in cosmetics such as face powders, as flow conditioner and for oil absorption. Silica gels also serve as drying agents, protecting a wide variety of products during shipment and storage.

Pyrogenic (fumed) silica is manufactured by using the high temperature hydrolysis process developed in the beginning of the 1940s. It consists of agglomerated and aggregated primary particles, typically between 5 and 100 nm. The aggregates, which are fused and chemically bonded primary particles, typically are of size between 100 nm and 350 nm. The aggregates in turn form agglomerates typically in the range from 150 nm up to the several 100 µm. Pyrogenic or fumed silica is used in silicone rubber applications, as a reinforcement and thixotropic agent in plastics, gel coats, sealants and adhesives, cosmetics and toothpastes. Pyrogenic silica is also used in coatings and printing inks, as a free flow, antistatic agent in animal feedstuffs and hygroscopic powders and as an antifoaming agent in the manufacture of paper, decaffeinated coffee and tea.

Cerium dioxide (CeO_2)

Normally cerium dioxide is produced by the oxidation of cerium hydroxide and cerium carbonate. Technical grade CeO_2 is generally present as micro- or nanoscale white to light yellow powder. Cerium dioxide gives infrared filters and is found in colour television tubes. Together with cobalt it is used in the production of powerful magnets. In addition, cerium dioxide is used as a polishing agent for optical glasses and for silicon wafers, and is applied as a grinding medium for computer parts, camera phone lenses, or CD player lasers.

Nano-structured cerium dioxide, among other products, is used as an oxygen-storing diesel additive in vehicle exhaust catalysts. It enables oxidation of carbon monoxide and excess hydrocarbons into CO_2 even when there is a temporary lack of oxygen in the exhaust mixture. During that process, CeO_2 is reduced to Ce_2O_3 that is re-oxidized later as soon as there is enough oxygen again in the exhaust gases. In fuel cells with other rare-earth metal oxides, coated CeO_2 particles are applied to improve the oxygen ion conductivity and to enable reduced operating temperatures. Moreover, nano-structured CeO_2 possesses an ideal UV absorber and is therefore used as an additive in lacquers and coatings for wood preservatives to enhance their UV stability.

Table 7. Main application for CeO_2 nanoparticles (Piccinno et al., 2012).

Main applications	% of total use
- Chemical mechanical planarization	45-80
- Fuel catalyst	1-50
- UV-coatings, paints	5-10

Barium sulfate

Barium sulfate is found as crystals which due to their high density are referred to as baryte or barite. The global barite mine production in 2013 was 8 180 Ktons. A USGS report (2013) states that EU produced 3% of the total production (about 245 Ktons). Proportion of nano is not reported. The litterature review (isi web) using $BaSO_4$/Baryte and Nano* as key words, revealed a very recent development of nano_$BaSO_4$. The first scientific paper published in 1996 was followed by less than ten during the last 5 years. Since 2008 less than 10 papers are published each year. However barite is used as micrometric particles for long time as detailed further.

The major quantity of the barium sulphate (80%) that is obtained by mining is used in oil and natural gas production to obtain high-density drilling fluids for flotation which keeps the boreholes free of rock. No data about the proportion of nano sized baryte in the drilling fluids can be found. Only one US patent (2012) details the use of nano barium sulphate.

Barium sulphate also serves as filler in the plastics and the paint and varnish industries. It increases the plasticity and weight of plastic materials that are used for sound insulation in e.g., car mats, carpet coatings, or plastic sewage pipes. In the paint and varnish industry, high-quality barium sulfate is used as filler mainly due to its inertness and high density. It improves the volume and consistency, viscosity and workability of e.g., fillers, surfacers, and primers. Blanc-fixe is added for easy glazing of glossy papers and photographic papers (barite papers). Burning of such papers leaves whitish barium sulfate deposits. In the textile industry, barium sulfate is found as a finish for linen goods and an agent for rayon matting during etching and printing. Due to its high coefficient of absorption for gamma radiation and X-radiation, barium sulfate is used in concrete (barite concrete, barite cement) that screens nuclear reactors. Nanoscale $BaSO_4$ is also very promising as additive to dental and bone cements. It is contained, in addition, in numerous radio-opaque substances (radio-opaque barite).

Among all listed applications of $BaSO_4$ the ratio or the proportion of nanometric fraction is almost unknown. Indeed if few scientific papers detailed how nano-$BaSO_4$ can be used and incorporated within various matrixes (plastic, drilling sludges…) the quantity of Nano-$BaSO_4$ exchanged by the world market is not detailed. However, based on granulometric distributions, the amount of nano (<100nm) can be estimated to about 1.5% in mass of the total production representing about 3675 tons for EU.

In EU, about 70 % of the blanc-fixe produced is used in coating compounds. Blanc-fixe is brighter than barite. It comes in different particle sizes for use in e.g., primers and fillers for automobile finishing, industrial varnishes, building paints and construction coatings, wood varnishes, and printing inks. In covering coats and enamels, it is used as “spacer” to improve titanium dioxide pigment scattering or to avoid flocculation of organic or inorganic colored pigments. Compounds that consist of zinc sulphide and barium sulfate as a white pigment (lithopone) have become less important.

Blanc-fixe is used to improve the plasticity of plastics and serves as “spacer” (see above) for white pigments and colored pigments. Moreover, it is applied to increase the surface hardness and scratch resistance of polyolefins, to produce tintless white films or translucent plastics and to enhance the plasticity of many types of semi-crystalline thermoplastics. Medical devices such as catheters or drainage pipes, and toys which may be swallowed by children benefit from the powder’s capability to absorb X-radiation. Likewise, blanc-fixe improves the frictional behavior of particular synthetic-fiber surfaces.

For the latter applications, the definition of ‘pigment’ does not help in determining the proportion of Nano-$BaSO_4$. Indeed pigment refers to micrometric sized powders. Even if nanometric fractions exist in any pigment powder the accurate proportion if generally not detailed.

Drilling applications although representing approx 80% of the world Ba comsumption is poorly documented in the scientific literature. Web of Science searches with keywords such as drilling fluid/mud barium (excluding the term "nano") returns less than 30 matches. Most environmental papers deal with off shore situation. There is some data showing that BaSO4 is mainly micron sized. For EU, it is estimated that 30% of the produced nano-BaSO4 is used for drilling applications (about 1103 tons) while the other 70% are used in plastics, paints and varnish industries (2573 tons).

Medical applications (X-ray imaging) have their own set of regulations regarding exposure to humans (and therefore probably out of the scope of Nanoreg), but they are important in terms of enviromental exposure by their discharge through feces in the wastewater systems.

Silver (Ag)

Silver and silver products have been known for years for their prestige (jewellery and tableware) and effect in hygiene. In the 20th century, the expansion of the photographic industry made increase the use of silver significantly, but electronic photography has decreased the use considerably. However, photographic use still represents 8% of the worldwide silver use, whereas biocidal silver represents only a very small fraction of worldwise silver use (less than 1%). Nowadays the use of silver is increasing in a wide range of applications.

Concerning the antibacterial properties, nanosilver is currently widely used in medical care products, such as in bandages to protect patients against infections. It has also been used in catheters. It can be expected that, with prices of medical applications of nanosilver decreasing, their use will increase (SCENIHR, 2014).

Some examples of consumer products containing nanosilver include food packaging materials, food supplements (these two applications are not allowed in the EU unless authorized), textiles, electronics, household appliances, cosmetics, medical devices, water disinfectants and room sprays. Currently, tracking products that contain nanosilver is difficult because the products are packaged under numerous brand names, and, with a few exceptions, current labeling regulations do not require that the nanomaterial be listed specifically as an ingredient. Regulation dealing with labeling includes Regulation (EC) No 1223/2009 on cosmetic products, Regulation (EU) No 1169/2011 on the provision of food information to consumers and Regulation (EU) No 10/2011 on plastic materials and articles intended to come into contact with food.

A list of application of silver and silver nanoparticles is shown in Table 8.

Table 8. Main application for silver and silver nanoparticles (reproduced from the SCENIHR, 2014).

Home consumer products	Fabric conditioners, baby bottles, food storage containers and salad bowls, kitchen cutting boards, bed mattress, vacuum cleaner, disposable curtains and blinds, tableware, independent Living Aids - bathroom products, furniture (chairs), kitchen gadgets and bath accessories, dishwashers, refrigerators and washing machines, toilet tank levers to sink stoppers, toilet seat, pillows, and mattresses, food storers, containers, ice trays, and other plastic kitchenware, hair brush, hair straightener, combs, brushes, rollers, shower caps. Toothpaste, cosmetic, deodorants, toothbrushes, tissue paper, epilator, electric shaver. Pet shampoos, feeders and waters, litter pans, pet bedding and shelter, paper, pens and pencils, ATM buttons, remote control, handrails (buses), computer keyboards, hand dryers, wireless voice communicators with badge and the sleeves, yoga mat, coatings for use on laptop computers, calculators, sheet protectors, name badges and holders, shop ticket holders, media storage products, laminating film, report covers and project folders, photo holders, memory Book, office accessories, transparency film, collapsible coolers
Healthcare	Wounds dressings, antiseptics, hospital beds and furniture
Clothing and fabrics	Baby clothes, underwear, socks, footwear, various fabrics and vinyls, bath towels, quilts, sleeping bags, bed linens, pillows, quilts, mattress protectors and towels
Food	Packaging, nanobiotic poultry production
Construction	Powder coating (door knobs), wall paints, air conditioning, epoxy resin floor, PVC wall cladding, antimicrobial flooring, metal suspended ceiling systems, window blinds and shading systems, shelving systems, decorative wood laminates, electrical wiring accessories, notile panels (alternative to standard tiling), hygienic laminated surfaces, wallpaper, borders and murals, carpet and carpet underlay, seals (door for cooler doors and freezer cells, tank lids, mixers and kneading machines, hospital doors, for vibrating screens/vibrosieves in the pharmaceutical industry)
Disinfectants	Agricultural disinfectants, industrial disinfectants, aquaculture disinfectants, pool disinfectants

According to the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR, 2014), the applications of nano-silver in consumer products can be categorised in several main categories and subcategories of products (Table 9 and Table 10). As noted in these tables, the product categories "Personal care and cosmetics" and "Textiles and shoes" are the categories with more product in this inventory.

Table 9. Nanosilver consumer products categories (reproduced from SCENIHR, 201).

Product category	Number of Products (%of total)	Subcategory	Number of products
Textiles and shoes	71(29)	Clothing	49
		Other textiles	18
		Coating	4
Personal care and cosmetics	68 (28)	Hair care	25
		Skin care	27
		Baby care	12
		Oral hygiene	4
Home furnishing and household products	46(19)	Packaging	4
		Cleaning products	15
		Coatings	14
		Cooking	1
		Paint	12
Appliances	23 (9.5)	Large appliances	15
		Laundry and clothing care	8
Health care	11 (4.5)	Wound dressings	
		Other health care products	
Filtration, purification neutralization and sanitization	10 (4)	Water filtration and purification	6
		Air filtration and purification	4
Motor vehicles	8 (3)	Coatings/cleaning	8
Miscellaneous	3 (12)	Miscellaneous	3
Toys and games	2 (0.8)	Toys	2
Electronics and computers	1 (0.5)	Computer hardware	1

Because of its antibacterial properties nanosilver is widely used in medical and functional textiles to prevent infection or deodorise. Also, the use of nanosilver in more common textiles like household cleaning textiles, sportswear, gloves, socks, underwear and anti-odour clothes have been reported.

For Ag nanoparticles, it has been suggested that consumer electronics and conductivity is responsible for 10-20% of the total use (Piccino et al. 2012). A substantial fraction of the applications in consumer electronics is antimicrobial surface coatings in for example fridges and washing machines. An emerging application in the electronic components/conductivity sector is printed electronics using silver nanoparticle inks, where electronics circuits are printed with a range of printing technologies including inkjet printers. Recently, some major companies started to produce silver inks in larger quantities for this purpose. For example AGFA claims to produce 50 Kg per month. Based on this, we estimate that 550 Kg per year of AgNPs are used for printed electronics and conductivity (10% of the annual European production of 5.5 tons per year).

Ag nanoparticles applications as catalysts in fuel cells where recently described in the scientific literature in the research phase. A plausible application seems to be replacement of Platinum. One approach involves Ag core particles coated with a thin layer of Pd (Sekol et al. 2013). These particles are then used together with carbon nanotubes as catalyst in fuel cells with the aim of oxygen reduction. However, we find no proof that a substantial serial production has yet arrived for AgNP containing catalysts in this field. AgNPs are sometimes mentioned to be used as intercalation material in batteries (Toyalamat 2010). A silver-zinc battery that is today used in hearing aid applications is said to contain nanoparticles on the silver-oxide electrode, however it is unclear if these NPs are made of silver. Neither battery, nor fuel cell applications are quantified in recent inventories on the use of AgNPS (SCENIR 2014, WWICS 2014), therefore we decided not to carry out detailed mapping of uses for these applications due to no proof of commercial use at high enough quantity.

Table 10. Ag main applications (SCENIHR, 2014).

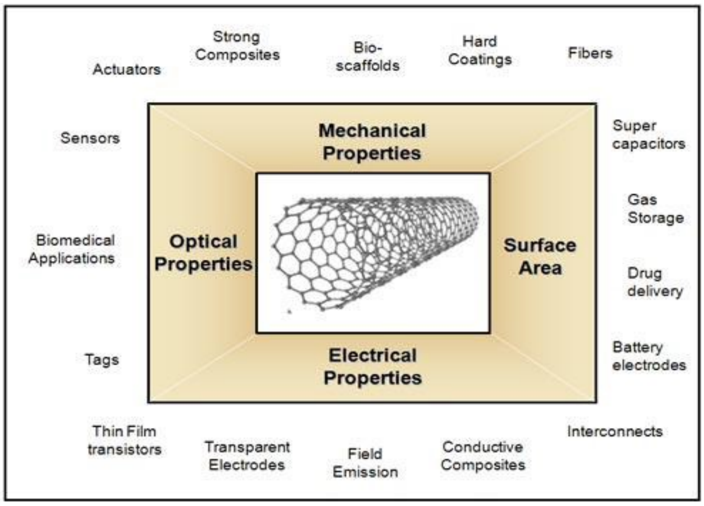
	Main applications		% of total use
-	Health & Personal care and cosmetics	-	80-100 %
-	Cleaning products	-	10-30%
-	Textile industry	-	10 %

Single-wall carbon nanotubes (SWCNT)

Carbon nanotubes (CNTs) have unusual properties which are valuable for nanotechnology, electronics, optics and other fields of materials science and technology. In particular, owing to their extraordinary thermal conductivity and mechanical and electrical properties, carbon nanotubes find applications as additives in various structural materials.

Important applications of nanotubes have been extensively investigated during the last years. A summary of the range of applications related to the specific properties where carbon nanostructure presents a distinctive advantage is given in Figure 3. Some of these applications have advanced to become commercial products while others are still in the developmental stage.

Figure 3. Possible applications for carbon nanotubes.



It is expected that the cost and availability of nanotubes of consistent quality will soon become more in line with the industrial needs, and consequently the pace of development will greatly accelerate. Some of the most widely investigated applications include conductive and high-strength nanotube/polymer composites, transparent electrodes, sensors and nanoelectromechanical devices, additives for batteries, field emission displays and radiation sources, semiconductor devices (e.g. transistors) and interconnects.

MWCNT

Multi-wall carbon nanotubes (MWCNT) are of special interest due to three properties: the electrical conductivity (as conductive as copper), their mechanical strength (up to 15 to 20 times stronger than steel and 5 times lighter) and their thermal conductivity (same as that of diamond and more than five times that of copper). A combination of these impressive properties enables a whole new variety of useful and beneficial applications, such as additives in composites, and components in electronic devices, batteris and fuel cells.

NanoCellulose

Cellulose is an indispensable part of our everyday life. It abounds in wood and plant fibers and it is used as a textile raw material, as a building material and also as an energy source. Today, almost all sustainable materials are including cellulose components. For years, cellulose structures in the nanometer range are isolated out of different raw materials (e.g. wood, annual plants, tunicin). Such cellulose is then referred to as nanocellulose. The properties of nanocellulose (e.g. mechanical properties, film-forming properties, viscosity etc.) make it an interesting material for the preparation of composite materials (e.g. packaging) and in the paper, board and food industries.

2.4.1.3 Existing exposure data

According to the European Chemicals Agency (ECHA) requirements on information and chemical safety assessment, exposure of substances in the workplace refers to external exposure. Substances in the workplace may come into contact with the body and possibly enter into it by inhalation, by contacting and passing through the skin (dermal route), or swallowing (ingestion). The exposure can be defined as the amount of the substance ingested, the amount in contact with the skin and/or the amount inhaled (represented by the concentration of the substance in the breathing zone of a worker) (ECHA, 2012b). Usually, it does not refer to concentrations within the body, determined by the amount of the substance absorbed from the digestive system, respiratory system or entering the body through the skin.

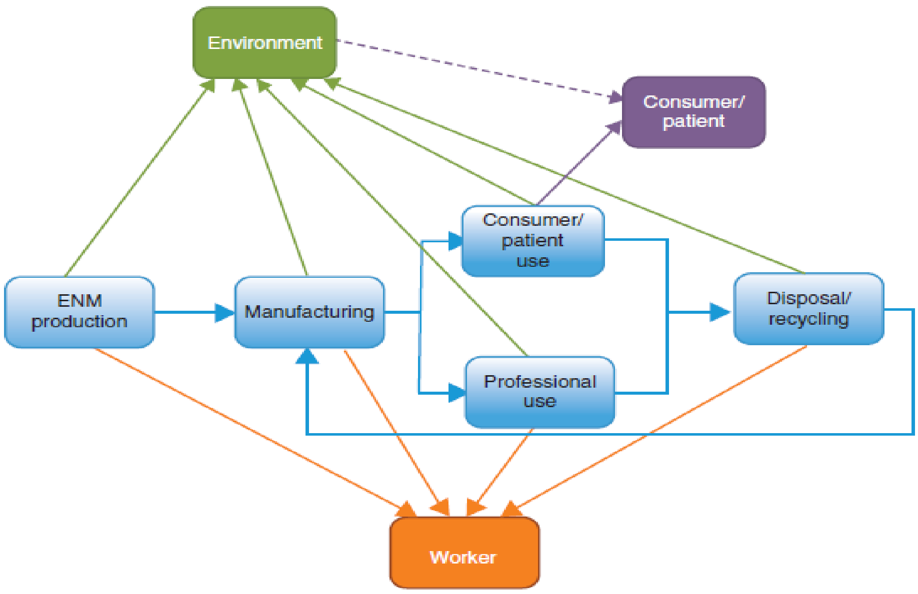
ECHA Guidelines were basically developed for soluble chemical compounds and not for engineered nanomaterials (EMN). Therefore, a revision of these protocols was proposed and was included in the RIP-on 3, which collects the corresponding Exposure Scenarios (Aitken et al., 2011). Changes were recommended to provide more information on the technical issues related to the measurement on ENM, the need to consider other metrics, the applicability of simulation studies, and the limitations of models. An extensive appendix dealing with discrimination from background particles, measurement of size distribution, maximum relevant size, spatial and temporal variability, choice of metric, high aspect ratio nanomaterials, measurement instruments and sampling strategy was developed. Moreover, it recommended consideration of other units, in addition to mass based ones for inhalation. RIP-oN 3 also recommended the use of simulation models, though it pointed that the existing models had not been appropriately tested with ENM.

Understanding uptake across different routes of exposure is necessary, although limited data is currently available. Factors that may influence ENM uptake include aerodynamic and hydrodynamic size, charge, surface area, surface chemistry and shape (Jones et al., 2014). In addition to the differences in uptake between exposure routes, these can in themselves also modulate mode of action and toxicity, since toxicity is greatly affected by interaction with the corresponding biological media (Johnston, Brown, Kermanizadeh, Gubbins, & Stone, 2012).

Occupational exposure to nanomaterials receives the most attention in the peer-reviewed literature, as the exposure during the synthesis of nanomaterials and manufacture of nano-enabled products would potentially be the highest one. Exposure can occur as a single event, as a series of repeated events or as continuous exposure. When developing an exposure assessment, the levels of exposure, either obtained from measurements or models, must be considered, as well as other parameters such as duration and frequency of exposure.

As it can be observed in Figure 4, occupational exposure to ENM may occur during very different life cycle stages. The most studied ones are the production of nanomaterials (e.g. recovering from reactor, packing...) and their use in the manufacture of nano-enabled compounds (e.g. weighing, mixing...). But occupational exposure to ENM may also take place during the end of life stage, such as recycling andother waste treatments (European Comission, 2012).

Figure 4. Life cycle stages and potential exposure of workers (orange lines), consumers/patients (violet line) and the environment (green lines) to ENM considered in this work. The dotted line "environment-to-consumer" was not considered (Nowack et al., 2012).



Usually, occupational exposure is studied by measuring the concentration of nanomaterials in the air at workplace, thus, considering inhalation as the main route of exposure. Direct dermal exposure and ingestion might also occur, but these routes are generally considered less important, commonly arising from accidents or bad practices.

The problem, as pointed by Hristozov et al., is that there is a "deficit of reliable measurements and models" as "the available data are often produced using non-standardized approaches, which makes them hardly comparable and difficult to use for univocal safety evaluations" (Hristozov et al., 2014). The lack of reliable measurements leads to uncertain and largely qualitative exposure estimations.

The consumer (member of the general public who may be exposed to a substance by using consumer products or articles) exposure is important because the possible means of controlling the exposure are very limited and cannot normally be monitored, or enforced beyond the point of sale of the products.

Consumer exposure estimation is often difficult due to limited data availability. It should normally address the consumer uses of a substance, a mixture or an article that contains the substance. Manufacturers/importers of substances and formulators may have different levels of information about exposure resulting from consumer uses of products (ECHA, 2012a). In the RIP-oN, 3 the adaptation of ECHA Guideline for the evaluation of consumer exposure was also considered.

The exposure route for the consumer is totally dependent of the type of use and application of the product, *e.g.* ENM in textiles may result in dermal exposure while the ones in products that are applied through an aerosol may be inhaled, deposit on the skin and possibly ingested.

There are few studies on the environmental release and fate of ENM. This is mainly due to a lack of methods to detect ENM in the environment. A particular problem is the distinction between engineered nanomaterials and incidental or natural (nano)particles. Apart from clear indications that nanomaterials interact with natural organic matter, there is also little information about the fate of nanoparticles in the environment.

INHALATION OF NANOPARTICLES

Inhalation is considered the main route of exposure for many ENM in most exposure scenarios. Exposure by inhalation is a function of the concentration of the substance in the breathing zone atmosphere and is normally presented as an average concentration over a reference period. For comparison with hazards after repeated or continuous exposure, a reference period of a full shift (normally 8 hours) is generally used. If the substance has the potential to cause acute health effects or if exposure is of intermittent short durations it may also be relevant to identify and evaluate exposure over shorter periods (ECHA, 2012b). Exposure to nano particles is generally expressed in mass units, number of particles and/or surface area of particles by volume of air. It is also recommended in ECHA Guidelines to give, when possible, the corresponding size distributions.

The deposition of nanoparticles in the respiratory tract is influenced by the aerodynamic diameter of the particles. In addition, breathing rate and mechanism (e.g. nasal or mouth) will also affect the rate and location of particle deposition in the respiratory tract. Individuals with existing lung diseases or conditions may also be susceptible to increase in nanoparticles deposition.

Although the research in occupational exposure is still limited, several articles have reviewed occupational exposure studies with experimental measurements. Some of them are general reviews (Kuhlbusch, Asbach, Fissan, Göhler, & Stintz, 2011; Nowack et al., 2012; Park et al., 2010; van Broekhuizen, van Broekhuizen, Cornelissen, & Reijnders, 2012) while others focused on specific ENM, such as CNT (Manke, Luanpitpong, & Rojanasakul, 2014), or ways of handling, such as spraying (Losert et al., 2014). Besides these reviews, it is worth mentioning the publication by Brouwer and co-workers, as it analyses 120 exposure scenarios in 19 enterprises (Brouwer et al., 2013). Altogether the mentioned documents are considered the state of the art on occupational exposure, and we did not perform any additional literature analysis.

Consumer exposure by inhalation has received less attention, and mostly products and processes with clear possibilities of exposure (eg: spray) have been studied. In addition to these, some degradation/aging studies are found. Some examples found in the literature are shown in Table 11. These studies conclude that free ENM are not generally released from polymeric matrices during the grinding of polymers (e.g., as a recycling step). As in any fine grinding process, release of fine, including nano-scale particles can occur, but these are also generally processed particles, i.e. polymeric particles with embedded/adsorbed particles (Göhler, Stintz, Hillemann, & Vorbau, 2010).

Table 11. Examples of consumer exposure by inhalation to different nanomaterials.

NM	Process	Duration	Measure	Background	Units	Technique	Comments
Ag (Quadros & Marr, 2011)	Spraying	Spray action	56	0	ng		
Ag (Lorenz et al., 2011)	Spraying	Spray action	From nd to 9	0	ppm		Different products
ZnO (Vorbau, Hillemann, & Stintz, 2009)	increasingly stressing surface treatments to coated parquet	3 cycles of 100 revolutions	From $1{\cdot}10^4$ to $3.5{\cdot}10^5$		Particles /run	CPC and SMPS	Different products. Tough no <100nm particles were measured, they are released embedded in the matrix
ZnO (Göhler et al., 2010)	Sander abrasion	1 sanding process	10^6-10^9	-	particles	SMPS	Measured particles are matrix releases. NM releases with the matrix
SiO_2 (Michel, Scheel, Karsten, Stelter, & Wind, 2013)	Spraying	Max. Conc. 1 min	0.035		$mg{\cdot}m^3$		

DERMAL EXPOSURE

It is well known since long ago, that the skin protects the body against external interferences and acts as an insulator and synthesis of vitamin D. For some substances or exposure situations the dermal route may be the main route of exposure. Substances may have local effects on the skin or may have the ability to penetrate skin and become absorbed into the body. Two terms are used to describe dermal exposure (ECHA, 2012b):

- *Potential dermal exposure* is an estimate of the amount of contaminant landing on the outside of work-wear and on the exposed surfaces of the skin.
- *Actual dermal exposure* is an estimate of the amount of contamination actually depositing on the skin. It is mediated by the efficiency and effectiveness of clothing worn and work practices used to minimize transfer of contamination from work-wear onto the skin.

There are three major routes of dermal contamination: by deposition (from air), by direct contact with the contaminant (e.g. immersion, splashes), and by contact with contaminated surfaces. Transfer of contamination from hands to other parts of the body may be an important part of skin exposure. Contaminated clothing can also be a source of exposure particularly of the hands when removing contaminated work clothing and/or PPE. Dermal exposure is generally expressed in terms of the mass of contaminant per unit surface area of the skin exposed.

The literature in skin penetration is quite abundant, but controversial, at the moment (Korinth & Drexler, 2013).In general, the intact skin has been shown to be an effective barrier for nanoparticles (Gontier et al., 2008), and it has been reported that titanium dioxide nanoparticles used in sunscreens do not go through the skin especially beyond the epidermis (Dowling, 2004). However, other studies showed that NP can penetrate damaged skin or through follicular orificies (Lademann et al., 1999), or even intact skin. For example, for silver nanoparticles, skin penetration rates less than 0.01 % have been published (Larese et al., 2009).

In addition to the uncertainties on the skin penetration of ENM, worker and user exposure to the skin has not been sufficiently studied and most papers focused on dermal exposure to cosmetics. Only very recently, the first studies on dermal exposure to ENM due to the release (e.g. aging, contact, abrasion…) from other products, such as textiles, were published. The literature in the field is summarized in Table 12.

Table 12. Summary of user exposure by dermal contact to different ENM (no healthcare products).

NM	Process	Duration	Measure	Units	Technique	Comments
Ag (textiles) (Kulthong, Srisung, Boonpavanitchakul, Kangwansupamonkon, & Maniratanachote, 2010)	Artificial sweats	24 h	0-322	mg/kg of fabric	TEM, ICP, GAAAS	Very variable depending on the type of silver, its concentration and sweat composition. Results vary from 0% release to complete silver release.
Ag (textiles) (Yan, Yang, Li, Lu, & Wang, 2012)	Perspiration to 3 different solutions	4 h	0.02-0.05	%	ICP-OES, SEM	Most released silver is Ag^{+} but NP aggregates found in solutions
Ag (textiles) (von Goetz et al., 2013)	2 different sweats (acid and basic)	30 min (rotating in washing machine)	nd-45 dis nd-23 NM	µg/g/L	Adapted ISO method 105-E04	Depending on the type of fabric and sweat.
TiO_2 (textiles)			nd			
Ag+TiO_2 (textiles)			Ag: 31-43 dis 45-61 NM Ti: 126-788			
Ag (Quadros et al., 2013)	Different simulated fluids (urine, sweat,...)	Depends on the fluid	0.5-38.3	%	ICP-MS	

INGESTION

Ingestion is another route whereby nanoparticles may enter the body. Most of the toxicity studies pertaining to nanoparticles focused on the respiratory tract exposures with few studies describing the gastrointestinal tract (Yah, Simate, & Iyuke, 2012). The gastrointestinal tract exposures usually occur either unintentional from hand to mouth transfer of the ENM or materials that contain ENM.

Considering occupational exposure, ingestion or oral exposure may occur in situations where there is exposure to aerosols and where contaminated skin or clothing may lead to exposure due to contact with the mouth region. It could be minimized if good hygiene practices are followed (segregating working and eating facilities, an adequate washing prior to eating, etc.). Therefore exposure by ingestion is not further considered in the assessment of workplace exposure, only when considering uncertainties in the exposure assessment as a whole (ECHA, 2012b).

ENVIRONMENTAL EXPOSURE

Environmental exposure to engineered nanomaterials (ENM) occurs through a number of compartments which includes water, soil and air. Nowack et al. (2013) evaluated recently the likelihood of environmental exposure to ENM based on material type and sectors. Based on this paper, sectors such as 'agricultural production', 'groundwater remediation', 'soil remediation' and 'medical textiles' followed by 'food processing', 'food packaging', 'chemistry/materials', 'cosmetics' and 'sports and outdoor clothing where ENM are incorporated into fibres' show the highest likelihoods for environmental exposure (Nowack et al., 2012).

In regard to fate modeling, existing studies use quite simplistic exposure models and may lack reliability in their predictive environmental concentration (PEC) predictions. Modeling requires input parameters such as transfer and partitioning coefficients and emission factors which at present can only be based on assumptions. Generally quantitative mass flow analysis is used based on, for example, production volumes and product contents of ENM. On this basis their transfer/release to environmental compartments is estimated under certain assumptions (e.g. temporal and spatial boundaries) and by applying estimated parameters and coefficients (e.g. for use, disposal, release etc).

2.4.1.4 Previously reported data gaps

OCCUPATIONAL/CONSUMER EXPOSURE

To date, one of the most relevant documents reviewing the state of the art on nanomaterials exposure in a regulatory context is the REACH Implementation Project – Specific Advice on Exposure Assessment and Hazard/Risk Characterization for Nanomaterials under REACH (RIP-oN3). The European Chemicals Agency transposed these findings directly into appendices to the REACH guidance documents, including some recommendations to be taken into consideration by registrants.

Based on the relevant findings of RIP-oN3, the following gaps pertaining to exposure assessment in NANoREG have been identified:

- The need for harmonized collection and analysis of data using relevant metrics to exposure. This would enable validation of models and based on this, standardized or new approaches can be developed.
- The development of improved measurements tools for assessment of exposure to NM with the possibility of multi-metric approaches (choice of metrics). The metrics currently used in risk assessment are based on mass or number. However, the most emerging additional metric identified for use in relation to the risk assessment of nanomaterials is surface area. This is based primarily on toxicological evidence relating particle surface area to inflammation, an indicator of toxicity. Thus, it seems to be a consensus that there should be sufficient characterization of the forms of a substance tested to allow the dose-response to be expressed in the different metrics –

number, surface area and mass. Hence, it is recommended that measurements should encompass assessment of at least mass, but where possible also number and/or surface area concentration.

- The development of the evidence base about the potential release of ENM for different activities and processes. This includes measurements in industrial facilities as well as laboratory which would provide the basis for more rapid gathering of data and information. Much work is required to assess the potential emissions of substances which contain ENM. Based on the collection of data, the efficacy of the release models could be validated. This applies both to release and exposure for humans and for the environment.
- More data is needed to be gathered across all the life cycle stages not only synthesis/manufacturing processes but use and end of life stages. The development of an improved sampling strategy is needed to take action of the multiple needs.
- Improved approaches for discrimination of background nanoparticle are required in order to estimate human and environmental exposure to ENM.
- Validation of exposure models for use with ENM.

ENVIRONMENTAL EXPOSURE

Regarding the detection and characterization of ENM in the environment, currently there is a lack of suitable methods for detection and characterization of ENM when they are embedded in complex matrices such as water, soil and food. Therefore, there is a need for optimization and development of analytical methods, including appropriate methods to extract the ENM from the matrix, to quantify the "background" of naturally occurring nanoparticles, as well as the generation of reference materials.

Additional knowledge gaps identified in the RIP-oN3 final report are:

- Validated methods for quantification of ENM releases from materials and processes.
- Characterization of released ENM.
- Assessment of potential emissions to the environment relevant to ENM.
- Development of analytical methods to measure/verify actual exposure concentrations, aggregations/agglomeration behavior and stability of ENM in soil.
- Reliable exposure models for ENM.

2.4.2 Mapping of uses

The first step was to generate life cycle maps for the most relevant applications identified in section 2.4.1.2 and summarized in Table 13, as a way to identify the different tasks/activities across relevant value chains. Each of the applications was assigned to one of the partners involved in the task. These partners were then responsible for collecting the data and generate the life cycle map and associated exposure scenarios. If an ENM was used in different supply chains, several exposure scenarios became relevant (Figure 5).

Figure 5. Overview of a general life cycle map.

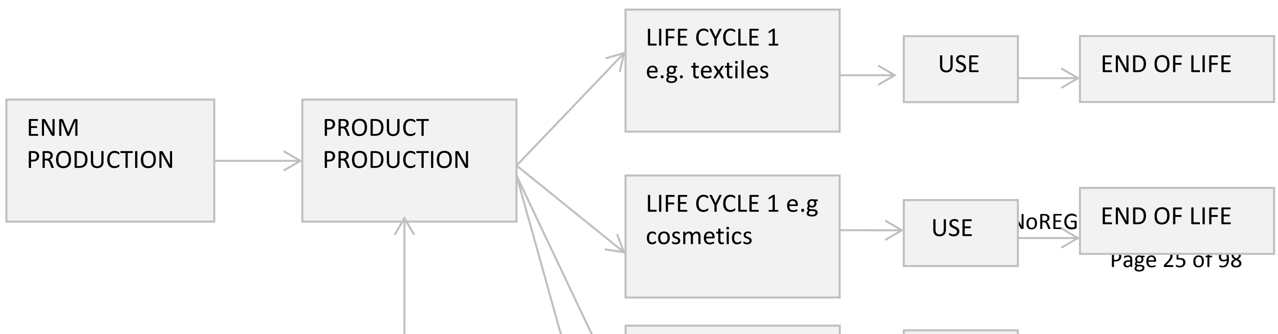


Table 13. Summary of the main applications in industry for selected nanomaterials.

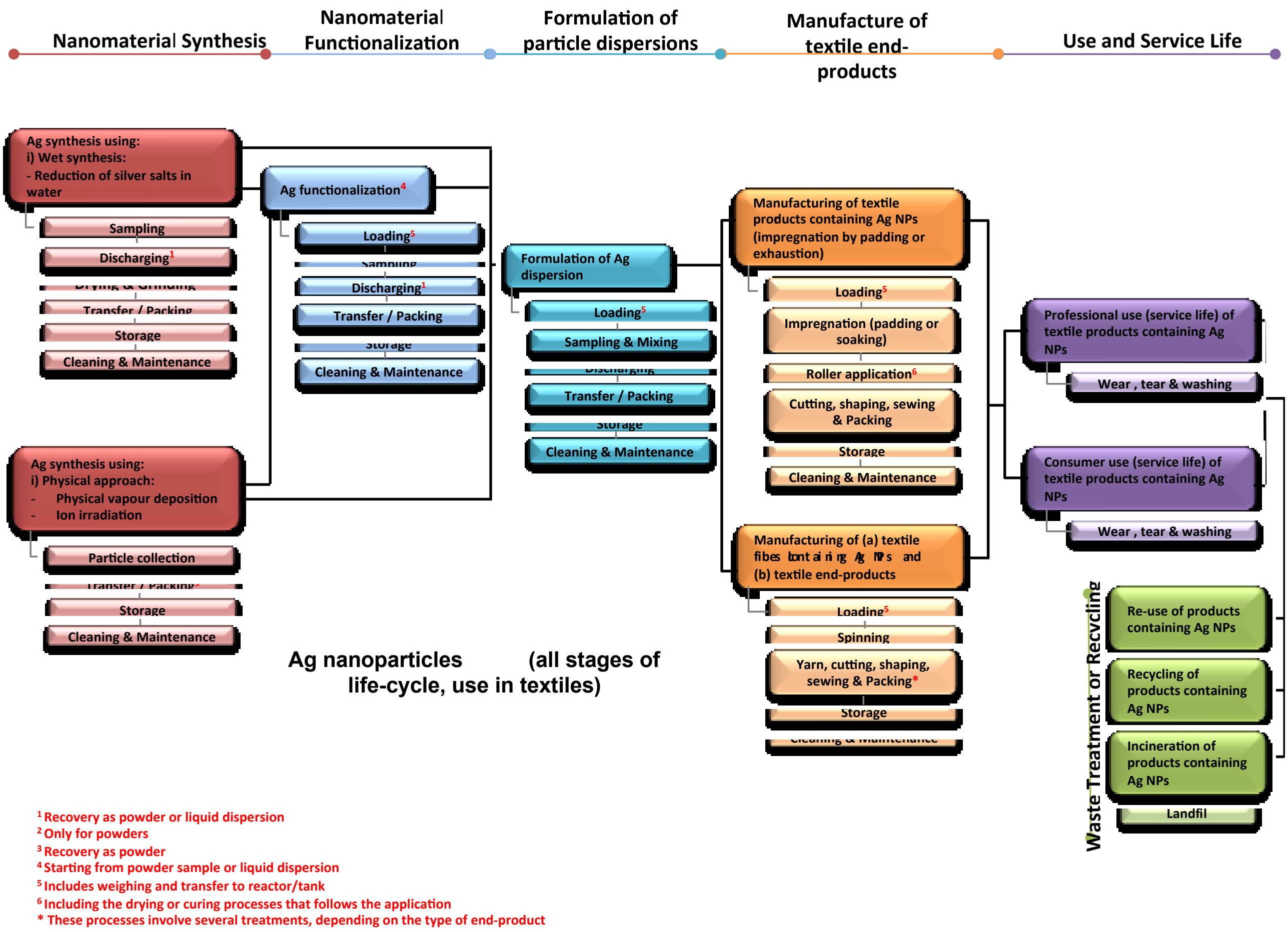
Nanoparticle	Production volume	Main applications	*Responsible partner*	*Status*
SiO_2	n.d.a.	Construction industry	CEA	√
		Electronics	CEA	√
		Packaging	ITENE	√
TiO_2	70-80%	Cosmetics	LEITAT	√
	<20%	Paints and Coating	ITENE	√
	<20%	Plastics (Use as reinforcing material in plastic matrices)	ITENE	√
	n.d.a.	Textiles	LEITAT	√
		Use as reinforcing material in cement	AIDICO	√
ZnO	70%	Cosmetics	ITENE	√
	30%	Paints& coatings	ITENE	√
	n.d.a.	Construction	AIDICO	√
CeO_2	45-80%	Chemical-mechanical planarization (electronics)	CEA	√
	1-50%	Fuel catalyst	CEA	√
	5-10%	UV-coatings, paints	CEA	√
	n.d.a.	Packaging	ITENE	√
Ag	80-100%	Health&Personal care and cosmetics	ITENE	√
	10-30%	Cleaning products	ITENE	√
	10%	Textile industry	LEITAT	√
	n.d.a.	Construction	AIDICO	√
		Coatings and paints	ITENE	√
		Packaging	ITENE	√
		Electronic components	LTH	√
CNT	70%	Composites & polymer additives	IOM	√
	50%	Energy applications	LTH	√
$BaSO_4$	n.d.a.	Oil & natural gas production	CEREGE	√

Nanoparticle	Production volume	Main applications	*Responsible partner*	*Status*
		(lubricants application for drilling)		
		Plastics	CEREGE	√
		Paints & varnish industries	CEREGE	√
NanoCellulose	n.d.a	Paper & paper board	CEA	√
		Composites (plastics, films, paints, foams, packaging)	CEA	√

n.d.a.: no data available

An example of the life cycle maps developed in this task is shown in Figure 6, and the rest are collected in Annex 1.

Figure 6. Life cycle map for Ag nanoparticles used in textiles.



The life cycle maps have been the basis for the identification of the Contributing Exposure Scenarios (CES), which cover tasks where exposure is likely to be similar, and altogether form the Generic Exposure Scenarios (GES). As an example, table 14 shows the preliminary GES and CES identified for Ag nanoparticles used in textiles (tables for all other ENMs are collected in Annex 2). The identification and description of these CES was based on data provided by the partners. It is important to mention that these CES might be modified/extended in the future, if necessary.

Table 14. Identified Uses (IU) relevant for nano Ag used in textiles.

IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	GES CODE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
IU 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	GES Ag 1 (Nano Ag synthesis)	CES 1.1. Sampling during synthesis CES 1.2. Discharge from reactor/tank CES 1.3. Transfer to small containers (including weighing) and packing CES 1.4. Storage CES 1.5. Cleaning and maintenance
IU 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)		CES 2.1. Sampling during synthesis and physical separation CES 2.2. Drying and grinding processess CES 2.3. Transfer to small containers (including weighing) and packing CES 2.4. Storage CES 2.5. Cleaning and maintenance
IU 3	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition		CES 3.1. Synthesis (including collection of particles) CES 3.2.Transfer to small containers (including weighing) and packing CES 3.3. Storage CES 3.4. Cleaning and maintenance
IU 4	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	GES Ag 2 (Ag Functionalization)	CES 4.1. Loading (including weighing and transferring to reactor/tank) CES 4.2. Sampling during functionalization CES 4.3. Discharge from reactor/tank CES 4.4. Transfer to small containers (including weighing) and packing CES 4.5. Storage CES 4.6. Cleaning and maintenance
IU 5	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)		CES 5.1. Loading (including weighing and transferring to reactor/tank) CES 5.2. Sampling during functionalization CES 5.3. Drying and grinding processess CES 5.4. Transfer to small containers (including weighing) and packing CES 5.5. Storage CES 5.6. Cleaning and maintenance
IU 6	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	GES Ag 3 (Formulation of Ag dispersion)	CES 6.1. Loading (including weighing and transferring to reactor/tank) CES 6.2. Mixing and sampling CES 6.3. Discharge from reactor/tank CES 6.4. Transfer to small containers (including weighing) and packing

IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	GES CODE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
			CES 6.5. Storage CES 6.6. Cleaning and maintenance
IU 7	Manufacturing of textiles containing Ag NP by Padding or Exhaustion	GES Ag 4 (Manufacturing of textiles containing Ag NPs)	CES 7.1. Loading (including weighing and transferring to reactor/tank) CES 7.2. Padding or soaking (impreganation treatments) CES 7.3. Roller application (including drying and curing processes that follows) CES 7.4. Cutting, shaping, sewing and packing. Textile manipulation CES 7.5. Storage CES 7.6. Cleaning and maintenance
IU 8	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of functional textiles		CES 8.1. Loading (including weighing, mixing and transferring) CES 8.2. Spinning CES 8.3. Yarn, cutting, shaping, sewing and packing. Textile manipulation CES 8.4. Storage CES 8.5. Cleaning and maintenance
IU 9	Professional Use of textiles containing Ag nanoparticles	GES Ag 5 (use)	CES 9.1. Usage (wearing) CES 9.2. Washing
IU 10	Consumer use of textiles containing Ag nanoparticles		CES 10.1. Usage (wearing) CES 10.2. Washing

2.4.3 Development and prioritization of exposure scenarios

2.4.3.1 Selection of exposure scenario content

Exposure scenarios typically contain information on the following points: the procedures involved during synthesis, use or disposal of the ENM; the associated operational conditions (OCs) of use; the Risk Management Measures and waste treatment measures which are necessary for safe use; and information about the exposure estimation and the models used for this purpose.

Within this task, exposure scenarios have been developed for prioritization purposes. Site-specific details were not available and could be rather variable. For this reason, only generic information, use descriptors and a subselection of typical exposure determinants were included. As a result, the template that was used to collect the information is simpler than other existing templates, such as the one developed for the MARINA project. The final template includes Use Descriptors (see Tables 15 and 16) and determinants of exposure (see Tables 17, 18, and 19). The selection of the most appropriate Use Descriptors was based on literature data and reports from other EU FP7 projects.

Table 15. Definition of use descriptors according to the ECHA Guidance**.**

Sector of Use (SU)	Describes the sector of the economy where the nanomaterial is used and has no relevance for exposure estimation.
Process category (PROC)	Describes the technical process or application in which the nanomaterial is used from

	an occupational perspective. PROCs are defined for workers only.
Product category (PC)	Describes the type of mixtures containing the nanomaterial on end-use. These PCs have to be used for consumer products and for transparency should also be assigned to industrial and professional end-uses.
Article category (AC)	Describes the type of article into which the substance has eventually been processed. These are only applicable for consumer end use.
Environmental release category (ERC)	Describes the broad conditions of use and emission from the environmental perspective.

Table 16. Relevance of the ECHA use descriptors in the different life-cycle stages.

Life-cycle stage	SU	PROC	PC	AC	ERC
Manufacturing	+	+	NA	NA	+
Formulation	+	+	NA	NA	+
Industrial end-use	+	+	+	NA	+
Professional end-use	+	+	+	NA	+
Consumer end-use	+	NA	+	+	+

NA: Not applicable

Due to the relative lack of information on the behavior of ENM during the end-of-life phase, and the fact that different end-of-life options exist and these are not usually product specific, no specific exposure scenarios were developed for this phase of the life cycle.

The exposure determinants that were used as criteria to prioritize exposure scenarios are summarized below. These criteria were selected so that the data could be easily collected at this stage of the project and could be useful to generate, based on a Weight of Evidence approach, a qualitative ranking of the exposure scenarios.

<u>Determinants of occupational exposure</u>

Several nanospecific control banding tools have been generated to identify potential high exposure (and sometimes risk) scenarios. For example, the CB nanotool (Zalk, Paik, & Swuste, 2009), the Groso method (Groso, Petri-Fink, Magrez, Riediker, & Meyer, 2010), Stoffenmanager nano (Van Duuren-Stuurman et al., 2012), and the Precautionary matrix (FOPH/FOEN, 2008). Such tools/methods are based on a series of exposure determinants that are relevant in occupational settings. Within this task, a subset of these exposure determinants was selected, based on two criteria: feasibility of obtaining the information required and impact on the overall exposure potential. It also needs to be kept in mind that the scenarios considered are hypothetical, thus the exposure scenarios have been filled according to literature and on the basis of own assumptions. Operational conditions can greatly vary from one industry to another, leading to scenarios of widely differing characteristics. In such cases, the most commonly reported conditions were selected. Inhalation was considered the major exposure route in occupational settings and the determinants of exposure selected were mainly relevant for this route of exposure.

Scores were assigned to each of the possible values for the exposure determinants so that later an algorithm could be defined to derive an overall 'exposure potential score' for each exposure scenario. Table

17 shows the scores selected for the exposure determinants to be used to evaluate occupational inhalation exposure. Values were adapted from Stoffenmanager Nano (see below), except from those assigned to the PROCs, which are adapted from ECETOC TRA. ECETOC TRA proposes different values for solids than for liquids. In all cases the most conservative values for industrial exposure prediction were used since the physical form parameter already takes into consideration possible differences between solids and liquids.

Stoffenmanager nano is a risk-banding tool based on the conceptual model for occupational inhalation exposure to ENM described by Schneider et al. (2011). The model describes a stepwise transfer of ENM from the source (emission) via various transmission compartments to the receptor (immission). In our approach, activity emission potential was defined according to the scores given by the ECETOC TRA associated to each PROC. With respect to substance emission potential, the selected determinants were physical form (solid, liquid and powder) and weight fraction, both with assigned multipliers adapted from those given by the Stoffenmanager tool (Table 17). As mentioned above, due to the wide variability within scenarios and the lack of data, other parameters have been not included, such as dustiness of powders or granules, moisture content for solids or liquid viscosity. Transmission is also considered as the dispersion/dilution (near-field/far-field), surface deposition (indirectly), re-suspension (surface contamination), localized controls, personal enclosure are taken into account in Stoffenmanager nano. For the same reason, in this work only natural and/or mechanical ventilation and separation (or personal enclosure) have been included to define the Exposure Scenarios, and localized controls in proximity to the source, segregation of the source, personal behavior and surface contamination have been excluded from the evaluation. In the Stoffenmanager nano, immision by the worker is addressed, eg. whether a protective mask is used, which has been also considered in this work.

Table 17. Occupational exposure determinants included in the Exposure Scenario (ES).

DETERMINANTS OF OCCUPATIONAL EXPOSURE			
MATERIAL CHARACTERISTICS		**Scores - Inhalation**	**Scores - Dermal**
Physical form (PF)	Powders	1	na
	Liquids	0,3	na
	Solids	0,1	na
Weight fraction (WF)	Small < 10% -20%	0,05	0.05
	Substantial 20-80%	0,75	0.75
	Main component 80- 100%	1	1
CHARACTERISTICS OF PROCESSES			
Process category (PROC)	PROC1 to PROC25*	0.01 to 1000*	0.03 to 141*
OPERATIONAL CONDITIONS			
Duration of activity/use (D)	1-30 min/day	0,06	na
	0.5-2 h/day	0,25	na
	2-4 h/day	0,5	na
	4-8 h/day	1	na
Frequency of activity/use (F)	1 day/year	0,01	na
	1 day/month	0,05	na
	1 day/ 2 weeks	0,1	na
	1 day/week	0,2	na
	2-3 days/week	0,6	na
	4-5 days/week	1	na
General Ventilation (GV)	Spraying booth	0.1	na

DETERMINANTS OF OCCUPATIONAL EXPOSURE			
	Natural/mechanical ventilation	3	na
	No general ventilation	10	na
RISK MANAGEMENT MEASURES			
Localized controls (LC)	Without LEV	1	na
	With LEV	0,3	na
Separation (SEP)	Absence of cabin	1	na
	Worker works in a cabin	0,1	na
Respiratory protection (PPE-R)	Yes	0,4	na
	No	1	na
Hands protection (PPE-D)	Yes	--	0,1
	No	--	1

*The scores for process category were based on those proposed in ECETOC.TRA (see Annex III for details)

na – not applicable

A similar approach was followed for determinants of occupational dermal exposure (Table 17). Values assigned to the PROCs, and hand protection factors (acting as a mitigation factor) were adapted from ECETOC TRA guidelines, while the scores for weight fraction categories, as in the case of inhalation, were taken and modified from Stoffenmanager nano. Local Exhaust Ventilation (LEV) was not applied to reduce initial dermal exposure, following a conservative approach. Moreover, unlike inhalation exposure, duration of work activity does not apply to high dustiness solids, such as most ENM, since the effect of duration on the fate of the substance once deposited on the skin is difficult to predict (see ECETOC TRA technical report 114). Therefore, ECETOC TRA predicts dermal exposure expressed as the cumulative 8-hour skin loading.

<u>Determinants of environmental exposure</u>

ENM levels in different environmental compartments will depend on the release of ENM to the environment and their fate, including transformations and transport. These processes are partially dependent on the properties of the site and on the properties of the ENMs. Therefore, for pragmatic reasons, within this task, we only considered release to the environment as determinant of environmental exposure.

At the moment, there is very limited real data on environmental releases of ENM from industrial processes, although some assumptions have been derived in previous publications. In the case of manufacture of nanoproducts, Gottschalk and Nowasch (2011) assume uniform probability distributions ranging from 0 to 2% of the ENM produced on the direct release to the environment. Generic worst-case scenario release coefficients for formulation of mixtures (not embedded into a matrix) considers that 2.5% are released to the air, 2% to the surface waters before reaching a sewage treatment plant and 0.01% to soils.

During the use phase, intended and unintended release of ENMs can occur. The unintended release of ENMs typically results from non-point sources such as sunscreens while the intended release results from point sources such as groundwater remediation. The release of ENMs from products during their use depends on several factors such as the amount of ENMs in the product, how the ENM is embedded in the product, the product lifetime and the use of the product. Generally, factors such as a low rate of use and strong fixation would increase the likelihood of ENMs entering the disposal phase, while a loose incorporation of ENMs in the product or an intense use will most likely not contain any ENMs at the time of disposal.

Some of these considerations are actually included among the aspects compiled by the Environmental Release Categories (ERC) that have been included as one of the Use Descriptors. The ERC were indeed defined to compile relevant aspects for environmental release (see Table 18) and can be used to estimate worst case environmental release values (chapter R.16 of the ECHA Guidance on information requirements and chemical safety assessment). Although these factors were initially generated for traditional chemicals, we considered that they were acceptable for the prioritization purposes of this task. For scenarios that have PROCs associated, the corresponding ERC have been taken (see Annex III table A.3), whereas for the use and the end-of-life scenarios ERC have been assigned case by case.

Table 18. Aspects considered deriving environmental release estimates for different environmental release categories.

Intended technical fate (purpose) of the substance during use (becoming part of an article, meant to react on use, meant to act as processing aid.
Life cycle stage
Dispersiveness of use
Contained application systems
Indoor or outdoor
Articles used under release-promoting conditions

Determinants of consumer exposure

On the basis of ECETOC-TRA for consumers, exposure determinants relevant for the three routes of exposure could be selected. The article category parameter could be used to select relevant exposure routes and default values for contact area, thickness of layer (which determines possible release), and amount of product used per application. In addition, weight fraction, physical form, frequency of exposure, and duration of exposure, which are already included in the excel file that we generated, could be included as exposure determinants for at least one of the exposure routes (Table 19). However, the main determinant of consumer exposure is possibly the transfer factor, for which very little information exists. Until such data becomes available, we consider that it would be misleading to rank products for their exposure potential on the basis of other parameters. In addition, it would not be possible to compare exposure through different routes, since the scores would be route specific. Therefore, generating information on transfer factors in different types of consumer products would be of high priority.

Table 19. Consumer exposure determinants included in the Exposure Scenario (ES).

MATERIAL CHARACTERISTICS	Inhalation	Dermal	Oral
Physical form (PF)	x	--	--
Weight fraction (WF)	x	x	x
CHARACTERISTICS OF PRODUCT			
Article category[1] (AC)	Amount application	Contact area * Thickness of layer	Volume of product swallowed
OPERATIONAL CONDITIONS			
Duration of activity/use (D)	x	--	--
Frequency of activity/use (F)	x	x	x

[1]Article category could be used to assign scores to amount of application (relevant for inhalation), contact area and thickness of layer (relevant for dermal), and volume of product swallowed (relevant for oral), in accordance to the default values defined by ECETOC TRA.

2.4.3.2 Prioritization of exposure scenarios

The data for the different exposure determinants compiled was used in a weight of evidence approach to generate an overall score to account for the exposure potential of each scenario. Three algorithms were generated, two for occupational and one for environmental exposure (see Table 20). Each of them was accompanied by thresholds that would classify a scenario into low (green colour), medium (yellow colour) or high potential for exposure (red colour). The thresholds were defined on the basis of the distribution of values obtained for the available exposure scenarios, so that around 25% of the scenarios would be classified as low exposure potential, and around 25% as high exposure potential. In the case of occupational inhalation exposure a wide dispersion of scores was obtained, mainly driven by the differences in the PROC scores. In the case of occupational dermal exposure values are much more similar across exposure scenarios. Whether this reflects reality or it is due to the fact that we missed some critical exposure determinants is unclear. In the case of environmental exposure, also rather similar scores were obtained. This could however be explained by the fact that our analysis was focused on main applications of ENM (so all of them had relatively high and similar production volumes), and the fact that ERC are highly dependent on the life cycle stage (highest in the use phase, which compensates the lowest amount of ENM used in this stage).

Table 20. Algorithms and thresholds used to rank exposure scenarios

	Algorithm for ranking score[1]	Thresholds for ES	Thresholds for CES
Worker exposure-inh (W_i)	PROC* PF*WF*D*F*GV*LC*SEP*PPE-R*Production volume	Low < 484, Medium 484-17640, High >17640	Low < 99, Medium 99 – 1870,31, High > 1870,31
Worker exposure-derm (W_d)	Wd= PROC*WF*PPE-D*Production volume	Low < 28, Medium 28 - 673, High > 673	Low < 5,66, Medium 5,66 – 107,59, High > 107,59
Environmental exposure	ERC * Production volume	Low < 0,98, Medium 0,98 – 16,67, High > 16,67	-

[1] PROC indicates process category, PF physical form, WF weight fraction, D and F duration and frequency of the activity, respectively, GV general ventilation, LC localized control, SEP separation, PPE-R respiratory protection, PPE-D dermal protection and ERC environmental release category.

As an example, Tables 21-23 show the tables summarizing the exposure scenarios for nano Ag in textiles and their scores for occupational inhalation, occupational dermal and environmental exposure, respectively. A link to the complete file with all the exposure scenarios considered can be found in Annex 4.

Table 21. Ranking of inhalation exposure scenarios for nano Ag used in textiles on the basis of use descriptors and other exposure determinants. Two exposure scenarios are provided as an example. Annex IV contains the link to the complete excel file.

GES CODE	IDENTIFIED USE (IU)	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY	PROCESS CATEGORY (PROC)	MATERIAL CHARACTERISTICS		OPERATIONAL CONDITIONS			RMM			RATING FOR THE POTENTIAL EXPOSURE		EU TONNAGE MANUFACTURED (t/year)	NEW RATING FOR THE POTENTIAL EXPOSURE	
					PHYSICAL FORM	WEIGHT FRACTION	DURATION (EXPOSURE TIME)	FREQUENCY	GENERAL VENTILATION	LOCALIZED CONTROLS	SEPARATION	RESPIRATORY PROTECTION (RPE)	CES	ES		CES	ES
GES Ag 1 (Nano Ag synthesis)	ES 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	CES 1.1. Sampling during synthesis	PROC4	Liquids	Small < 10% -20%	1-30 min/day	4-5 days/week	Natural/mechanical ventilation	Without LEV	Absence of cabin	No	0,27	2,13	5,5	1,49	11,69
			CES 1.2. Discharge from reactor/tank	PROC8b	Liquids	Small < 10% -20%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	With LEV	Absence of cabin	No	0,51			2,78	
			CES 1.3. Transfer to small containers (including weighing) and packing	PROC9	Liquids	Small < 10% -20%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	With LEV	Absence of cabin	No	0,68			3,71	
			CES 1.4. Storage	PROC1	Liquids	Small < 10% -20%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	Without LEV	Absence of cabin	No	0,0001			0,00	
			CES 1.5. Cleaning and maintenance	PROC8b	Liquids	Small < 10% -20%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	Without LEV	Absence of cabin	Yes	0,68			3,71	
	ES 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	CES 2.1. Sampling during synthesis and physical separation	PROC4	Liquids	Small < 10% -20%	1-30 min/day	4-5 days/week	Natural/mechanical ventilation	Without LEV	Absence of cabin	No	0,27	93,28	5,5	1,49	513,03
			CES 2.2. Drying and grinding processess	PROC4	Powders	Main component 80- 100%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	Without LEV	Absence of cabin	Yes	30,00			165,00	
			CES 2.3. Transfer to small containers (including weighing) and packing	PROC9	Powders	Main component 80- 100%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	With LEV	Absence of cabin	Yes	18,00			99,00	
			CES 2.4. Storage	PROC1	Powders	Main component 80- 100%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	Without LEV	Absence of cabin	No	0,01			0,04	
			CES 2.5. Cleaning and maintenance	PROC8b	Powders	Main component 80- 100%	0.5-2 h/day	4-5 days/week	Natural/mechanical ventilation	Without LEV	Absence of cabin	Yes	45,00			247,50	

Table 22. Ranking of dermal exposure scenarios for nano Ag used in textiles on the basis of use descriptors and other exposure determinants. Three exposure scenarios are provided as an example. Annex IV contains the link to the complete excel file.

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY	PROCESS CATEGORY (PROC)	MATERIAL CHARACTERISTICS	RMM	RATING FOR THE POTENTIAL EXPOSURE		EU TONNAGE MANUFACTURED (t/year)	NEW RATING FOR THE POTENTIAL EXPOSURE	
					WEIGHT FRACTION	PROTECTION OF HANDS (DPE)	CES	ES		CES	ES
GES Ag 1 (Nano Ag synthesis)	ES 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	CES 1.1. Sampling during synthesis	PROC4	Small < 10% -20%	Yes	0,03	0,21	5,5	0,19	1,14
			CES 1.2. Discharge from reactor/tank	PROC8b	Small < 10% -20%	Yes	0,07			0,38	
			CES 1.3. Transfer to small containers (including weighing) and packing	PROC9	Small < 10% -20%	Yes	0,03			0,19	
			CES 1.4. Storage	PROC1	Small < 10% -20%	No	0,00			0,01	
			CES 1.5. Cleaning and maintenance	PROC8b	Small < 10% -20%	Yes	0,07			0,38	
	ES 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	CES 2.1. Sampling during synthesis and physical separation	PROC4	Small < 10% -20%	Yes	0,03	2,81	5,5	0,19	15,44
			CES 2.2. Drying and grinding processess	PROC4	Main component 80- 100%	Yes	0,69			3,77	
			CES 2.3. Transfer to small containers (including weighing) and packing	PROC9	Main component 80- 100%	Yes	0,69			3,77	
			CES 2.4. Storage	PROC1	Main component 80- 100%	No	0,03			0,17	
			CES 2.5. Cleaning and maintenance	PROC8b	Main component 80- 100%	Yes	1,37			7,54	
	ES 3	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	CES 3.1. Synthesis (including collection of particles)	PROC2	Main component 80- 100%	Yes	0,1370	3,252	5,5	0,75	12,23
			CES 3.2.Transfer to small containers (including weighing) and packing	PROC9	Main component 80- 100%	Yes	0,6860			3,77	
			CES 3.3. Storage	PROC1	Main component 80- 100%	No	0,0300			0,17	
			CES 3.4. Cleaning and maintenance	PROC8b	Main component 80- 100%	Yes	1,3710			7,54	

Table 23. Ranking of environmental exposure scenarios for nano Ag used in textiles on the basis of use descriptors and other exposure determinants. Ten exposure scenarios are provided as an example. Annex IV contains the link to the complete excel file.

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	ENVIRONMENTAL RELEASE CATEGORY (ERC)	EU TONNAGE MANUFACTURED (t/year)	RELEASE ESTIMATION (WORST CASE SCENARIO)				RATING FOR THE POTENTIAL EXPOSURE
					To air	To Water	To Soil	Total	
GES Ag 1 (Nano Ag synthesis)	ES 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	ERC1	5,5	0,275	0,330	0,001	0,606	MEDIUM
	ES 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	ERC1	5,5	0,275	0,330	0,001	0,606	MEDIUM
	ES 3	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	ERC1	5,5	0,275	0,330	0,001	0,606	MEDIUM
GES Ag 2 (Ag Functionalization)	ES 4	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	ERC1	0,55	0,028	0,033	0,000	0,061	LOW
	ES 5	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	ERC1	0,55	0,028	0,033	0,000	0,061	LOW
GES Ag 3 (Formulation of	ES 6	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	ERC2	0,55	0,014	0,011	0,000	0,025	LOW
GES Ag 4 (Manufacturing of textiles containing Ag NPs)	ES 7	Manufacturing of textiles containing Ag NP by Padding	ERC5	0,55	0,275	0,275	0,006	0,556	MEDIUM
	ES 8	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of functional textiles	ERC5	0,55	0,275	0,275	0,006	0,556	MEDIUM
GES Ag 5 (use)	ES 9	Professional Use of textiles containing Ag nanoparticles	ERC 11B	0,55	0,550	0,550	na	1,100	HIGH
	ES 10	Consumer use of textiles containing Ag nanoparticles	ERC 11B	0,55	0,550	0,550	na	1,100	HIGH

2.5 Evaluation and conclusions

This deliverable focused on the identification of the main activities and processes that are conducted across the life cycle stages of the target nanoparticles identifying common uses and generic exposure scenarios. Gaps identified during this process are reported below (2.5.1) and together with the prioritization of exposure scenarios (2.5.2) can be the basis for the selection of case studies and the program of data collection in the following tasks in WP3.

2.5.1 Conclusions and gaps identified during the development of use maps and exposure scenarios.

In total, 26 applications were mapped with associated use descriptors and exposure determinants. It was not always feasible to fill in all data fields since the information needed to build exposure scenarios is rarely included in the peer-reviewed literature. Table 24 describes the main issues that partners have found when fulfilling the different fields in the mapping of uses.

Table 24. Overview of the evaluation of data of the mapping of uses process.

FIELD IN THE TEMPLATE FOR EXPOSURE SCENARIOS	EVALUATION OF DATA
Title Exposure Scenarios	Difficult to assign harmonized titles (ambiguous). Standardization and precision may be helpful.
List of all use descriptors related to the life cycle stage and the relevant uses under it	Minority data of industrial cases
PROCs – Process categories	Difficult to assign PROCs from processes. Sometimes tasks are part of different PROCs. Harmonization of task description is needed.
Product characteristics	Generally only the name of the nanomaterial was available
Amounts used	Generally not reported
Frequency of use	Generally not reported
Duration of use	Generally reported.
PPEs – Personal Protective Equipments	Frequently reported
Operational Conditions and general risk management measures	Usually not reported
Exposure estimation	Lack of standardization on measurement strategy and equipment

Despite these difficulties in obtaining data, some conclusions can be derived:

- Regarding the duration of use, the periods of handling of ENM are generally very short (< 15 min) while operation of maintenance and cleaning after the handling are the longest (~ 2h).
- Personal Protective Equipments (PPEs) are usually reported. The most commonly used PPEs are PPF3 mask, nitrile gloves, latex gloves and blouse for handling of ENM. Maintenance operations are also sometimes in a clean room with air extraction mask.

- Exposure estimation. Most often, during the tasks of handling, no increase of background has been reported. However, the most significant increases are reported during maintenance operations.

Additional limitations faced during the definition of the exposure scenarios and proposed actions are summarized in the table below.

Table 25. Limitations in existing data identified and actions proposed to address them.

IDENTIFIED LIMITATIONS	PROPOSED ACTIONS
A minority of publications address exposure at manufacturing facilities. The majority of the exposure scenarios are based on tasks/processes performed in research labs. Consequently, determinants such as duration and frequency are more related to laboratory workplaces than industrial ones even pilot scale.	Include experimental monitoring in industrial scale facilities.
To overcome the lack of available data regarding some determinants of exposure a precautionary principle has been applied. This can lead to an over estimation of exposure, and this may reduce the power to discriminate between critical Exposure Scenarios.	Complete data collection for the mapping of uses to store exposure data.
Few data are described in literature to estimate environmental release. The research projects are usually workplace-based and related to worker exposure only, thus limited information is reported related to environmental exposure/release. Conditions and measures related to on site/municipal sewage treatment plant are not usually reported.	In order to facilitate the collection of data that enables predicting environmental releases, additional fields related to the prediction of environmental release (see Annex 5) are suggested to be included in existing exposure scenario templates (e.g., that of MARINA).
Most data is available for initial life cycle stages, and barely any information is available on transfer factors from consumer products.	It is recommended focusing on ENM or nanoproducts during the use and end of life stages. Moreover, generating information on transfer factors in different types of consumer products would be of high priority.
End-of-life processes were no taken into consideration in the prioritization of exposure scenarios, as exposure during such processes would a priori be much more dependent on the end-of-life process than on the ENM application. In addition, end-of-life processes can change region by region.	
Absence of standard approaches and harmonized measurement strategies. Different ways of reporting results were found in the literature: individual results for each instrument (for each measurement separately), background levels and levels during the activity (it is difficult to report ranges during background measurements and during task measurements, as the two results are related), ratios between activity and background levels (drawback is that the level of the background might affect the ratio).	Need to define standard approaches to conduct exposure measurements and report data.
There is currently no consensus on what the most appropriate metric is	
There are currently no statutory workplace exposure limits specifically for nanomaterials	
There is a lack of knowledge about production amounts of ENM. When the task involves small quantities of nanomaterial with a little chance of it	Consider production volumes per application as preliminary estimates to

IDENTIFIED LIMITATIONS	PROPOSED ACTIONS
being released, the risk is low. However, when the task involves larger amounts of nanomaterial, exposure is higher and therefore the risk. Although there are a large variety of ENMs currently being used, there are no official statistics available on the amounts of ENMs currently used and products that contain them because to date there are not legal obligations for the notification of nanoproducts according to REACH regulation.	be refined when more accurate data becomes available.

2.5.2 Prioritization of exposure scenarios

The scores assigned to each exposure scenario can be used to rank them according to their potential exposure. Scores have no units and should be used only for ranking purposes, so it is conceived more as an approach to identify the critical exposure scenarios. Occupational exposure scores cannot be directly compared to those assigned to environmental exposure. Also inhalation exposure scores cannot be compared to those assigned to dermal exposure.

To summarize, the following tables show the ranking of the scenarios for inhalation exposure (Table 26), and the contributing exposure scenarios with highest scores (Table 27) for the core set of ENM selected in the NANoREG project. A similar exercise has been done for dermal exposure (Tables 28 and 29) and for environmental exposure (Table 30).

RANKING OF EXPOSURE SCENARIOS ON THE BASIS OF OCCUPATIONAL INHALATION EXPOSURE SCORES

Table 26. Ranking of exposure scenarios on the basis of occupational inhalation exposure scores.

RANKING	IDENTIFIED USE (IU)	SHORT ES TITTLE	SCORE
1	ES 1- SiO2 concrete	SiO2 synthesis using : burning SiCl4 in an oxygen rich hydrocarbon flame to produce a "smoke" SiO2	1175350
2	ES 1 - SiO2 electronics	SiO2 synthesis using : acidification of solutions of sodium silicate, then this gelatinous precipitate is washed and dehydrated	956313
3	ES 1 - CNT composites&polymers	Production/synthesis of CNTs using chemical vapour deposition (CVD)	155942
4	ES 2 - CNT composites&polymers	Production/synthesis of CNT using arc-vapour	155942
5	ES 3 - CNT composites&polymers	Production/synthesis of CNT using laser ablation	155942
6	ES 1- CNT energy	Production/synthesis of CNTs using chemical vapour deposition (CVD)	155942
7	ES 2- CNT energy	Production/synthesis of CNT using arc-vapour	155942
8	ES 3- CNT energy	Production/synthesis of CNT using laser ablation	155942
9	ES 1- SiO2 packaging	Manufacturing of Silica NPs by Thermal Decomposition	148504
10	ES 7- cellulose	Recycling and / or disposal	135000
11	ES 4-BaSO4-drilling	Use as well lubricant - Ba	77244
12	ES 7- SiO2 packaging	Preparation of nanofillers for compounding	74250
13	ES 4- SiO2 electronics	Recycling and/or disposal	72188
14	ES 1- cellulose	Cellulose synthesis using: i) Extraction from unripe coconut fiber	61500
15	ES 5 - CNT composites&polymers	Manufacturing of textile fibres	60233
16	ES 3-BaSO4-drilling	Preparation of Ba drilling fluids	58991
17	ES 2- TiO2 textiles	Nano TiO2 synthesis. Production of TiO2 NPs using the wet-chemical process (powder form)	51303

18	ES 4 - CNT composites&polymers	Manufacturing of intermediate composite materials containing CNTs	50243
19	ES 2- SiO2 concrete	Manufacturing concrete containing SiO2 NPs	50105
20	ES 2- SiO2 electronics	Manufacturing slurry containing SiO2 NPs	47106
21	ES 1- TiO2 construction	Nano TiO2 synthesis. Chloride process route	45049
22	ES 2- TiO2 construction	Nano TiO2 synthesis. Sulphate process route	42574
23	ES 2-BaSO4-plastics, paints and varnish	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (powder form)	39616
24	ES 3- TiO2 textiles	Nano TiO2 synthesis. Production of powdered TiO2 NPs using flame spray pyrolysis	37129
25	ES 5- SiO2 packaging	Quality control	37125
26	ES 2-BaSO4-drilling	Synthesis of Ba wet route	36704
27	ES 1-BaSO4-drilling	Synthesis if Ba dry route	35450
28	ES 4-BaSO4-plastics, paints and varnish	Formulation of Ba containing plastic starting from powders	34230
29	ES 4- cellulose	Manufacturing of paper - paper by product containing cellulose NPs	33469
30	ES 2- cellulose	Cellulose synthesis using: ii) Extraction from cotton fibers	30825
31	ES 1- TiO2 cosmetics	Manufacturing of cosmetics containing TiO2 NPs (formulation)	21140
32	ES 3- SiO2 concrete	Professional use of concrete containing SiO2 NPs	19594
33	ES 1- TiO2 paints	Manufacturing of TiO2 nanoparticles by chemical synthesis	19306
34	ES 3 - CeO2 catalyst	Professional use of catalyst	17844
35	ES 1 - CeO2 catalyst	CeO2 synthesis using : i) low temperature chemical precipitation method	17436
36	ES 4- CNT energy	Manufacturing electrode with added MWCNTs	15980
37	ES 6- SiO2 packaging	Cleaning	12375
38	ES 2- TiO2 paints	Weighing, bagging and packaging of silica TiO2 nanoparticles	11880
39	ES 3- SiO2 electronics	Professional use of slurry on electronic wafer	11540
40	ES 1- CeO2 paints	CeO2 synthesis using : i) low temperature chemical precipitation method	10506
41	ES 4- SiO2 packaging	Formulation solutions with nanomaterials	9926
42	ES 3- cellulose	Manufacturing of biomass/ bio fuel containing cellulose NPs	8685
43	ES 1- ZnO construction	Nano ZnO synthesis. Production of ZnO NPs using the wet-chemical process (powder form)	7104
44	ES 1- CeO2 electronics	CeO2 synthesis using : i) low temperature chemical precipitation method	6175
45	ES 5- cellulose	Professional Use of biomass	5750
46	ES 2- ZnO construction	Nano ZnO synthesis. Production of powdered ZnO NPs using physical vapor deposition	5412
47	ES 3- SiO2 packaging	Weighing, bagging and packaging of silica nanospheres	4950
48	ES 6- cellulose	Consumer Use of biomass	3875
49	ES 5-BaSO4-platics, paints and varnish	Manufacturing of plastics containing BaSO4 NP	3705
50	ES 8- SiO2 packaging	Melt compounding at laboratory scale	3630
51	ES 6 - CNT composites&polymers	Manufacturing of solid products with composite materials containing CNTs	2995
52	ES 7 - CNT composites&polymers	Manufacturing of textile products containing CNT fibres	2729
53	ES 4- SiO2 concrete	consumer use of concrete containing SiO2 NPs	2613
54	ES 2- CeO2 electronics	Manufacturing electronic devices cotainning CeO2 NPs CeO2 NPs are alo used as a polishing agent in electronic industry	2337
55	ES 5- TiO2 textiles	Functionalization leading to TiO2 nanopowder (starting from liquid dispersion or solid form)	2204
56	ES 3-BaSO4-plastics, paints and varnish	Formulation of Ba containing plastic starting from liquid dispersion	2076
57	ES 5- SiO2 concrete	Recycling and/or disposal	2063
58	ES 1- ZnO paints	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	1931
59	ES 1-BaSO4-plastics, paints and varnish	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (dispersion form)	1885
60	ES 3- TiO2 paints	Manufacturing of intermediates	1507

61	ES 1- TiO2 textiles	Nano TiO2 synthesis. Production of TiO2 NPs using the wet-chemical process (dispersion form)	1169
62	ES11 - CNT composites&polymers	Professional use (service life) of concrete products containing CNT	924
63	ES 8 - CNT composites&polymers	Manufacture of concrete products containing CNTs	889
64	ES 5- CNT energy	Asembly of battery	655
65	ES 2- Ag textiles	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	513
66	ES 2 - Ag construction	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	513
67	ES 2- Ag electronics	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	513
68	ES 3- ZnO paints	Manufacturing of intermediates	484
69	ES10 - CNT composites&polymers	Professional use (service life) of textile products containing CNT	433
70	ES3 - Ag packaging	Formulating solutions with nanomaterials	416
71	ES 3- ZnO cosmetics	Manufacturing of intermediates	412
72	ES 8- CNT energy	Recycling and disposal of products containing CNTs	408
73	ES 2 - CeO2 catalyst	Manufacturing cataylist cotainning CeO2 NPs	391
74	ES 3- Ag textiles	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	371
75	ES 3 - Ag construction	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	371
76	ES 3- Ag electronics	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	371
77	ES 4- TiO2 textiles	Functionalization leading to TiO2 colloidal solution (starting from liquid dispersion or solid form)	337
78	ES12 - CNT composites&polymers	Recycling and disposal of products containing CNTs	318
79	ES 6- TiO2 textiles	Formulation of TiO2 dispersions with other additives (starting from colloidal TiO2 solution or nanopowder form)	224
80	ES 1- Ag cleaning products	Manufacturing of Ag nanoparticles	193
81	ES 1- Ag packaging	Nano Ag synthesis. Production of Ag NPs	149
82	ES 3- TiO2 construction	Manufacturing of cements containing TiO2 NP	147
83	ES 7- TiO2 textiles	Manufacturing of textiles containing TiO2 NP by Padding or Exhaustion	121
84	ES 3- ZnO construction	Manufacturing of cements containing ZnO NP	98
85	ES 1- ZnO cosmetics	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	97
86	ES 3- CeO2 paints	Professional use of paints cotainning CeO2 NPs	85
87	ES 8- TiO2 textiles	Manufacturing of fibers containing TiO2 NP by Spinning and further manufacturing of functional textiles	85
88	ES 4- TiO2 paints	Formulation mixing with paints	67
89	ES 3- CeO2 electronics	Professional use (service life) of electronic devices	62
90	ES 4- CeO2 electronics	Consumer use of electronic devices	62
91	ES 2- Ag packaging	Nano Ag Weighing and bagging	59
92	ES 2- ZnO cosmetics	Weighing, bagging and packaging of ZnO nanoparticles	59
93	ES 5- Ag textiles	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	44
94	ES 2- CeO2 paints	Manufacturing paints cotainning CeO2 NPs used to provide an UV filter	43
95	ES 3- Ag cosmetics	Manufacturing of intermediates	41
96	ES 5- CeO2 electronics	Recycling and/or disposal	36
97	ES 6-BaSO4-plastics, paints and varnish	Professional Use of plastics containing BaSO4 nanoparticles	31
98	ES 7-BaSO4-plastics, paints and varnish	Consumer Use of plastics containing BaSO4 nanoparticles	31
99	ES 5 - CeO2 catalyst	Recycling and/or disposal	30
100	ES 9 - CNT composites&polymers	Professional use (service life) of solid composite materials containing CNT	29
101	ES 3- Ag cleaning products	Manufacturing of intermediates	27

102	ES 2- ZnO paints	Weighing, bagging and packaging of ZnO nanoparticles	18
103	ES 4- ZnO paints	Formulation mixing with paints	14
104	ES 2- SiO2 packaging	Filtre removal and particle packaging into vials	13
105	ES 1 - Ag textiles	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	12
106	ES 1 - Ag construction	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	12
107	ES 1- Ag electronics	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	12
108	ES 4 - CeO2 catalyst	Consumer use of catalyst	10
109	ES 5- CeO2 paints	Recycling and/or disposal	10
110	ES 1- Ag cosmetics	Manufacturing of Ag nanoparticles	10
111	ES 5 - Ag construction	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	9
112	ES 5- Ag electronics	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	9
113	ES 4- Ag textiles	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	7
114	ES 4- ZnO cosmetics	Formulation mixing in cosmetics	6
115	ES 2- Ag cosmetics	Weighing, bagging and packaging of Ag nanoparticles	6
116	ES 6- Ag textiles	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	4
117	ES 4- CeO2 paints	Consumer use of paints cotainning CeO2 NPs	4
118	ES 4- Ag packaging	Quality control	4
119	ES 7- Ag textiles	Manufacturing of textiles containing Ag NP by Padding or Exhaustion	2
120	ES 6- Ag electronics	Formulation of Ag ink dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	2
121	ES5- Ag packaging	Cleaning	2
122	ES 2- Ag cleaning products	Weighing, bagging and packaging of Ag nanoparticles	2
123	ES 8- Ag textiles	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of functional textiles	2
124	ES 4 - Ag construction	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	1
125	ES 4- Ag electronics	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	1
126	ES 6 - Ag construction	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	1
127	ES 4- Ag cleaning products	Formulation mixing with other products	1
128	ES 4- Ag cosmetics	Formulation mixing in Health&Personal care and cosmetics	1
129	ES 7 - Ag construction	Manufacturing of concretes containing Ag NP	0,42
130	ES 8 - Ag construction	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of concretes	0,34
131	ES 7- Ag electronics	Manufacturing of electronic components containing Ag NPs by printing	0,29
132	ES 6- Ag packaging	Preparation of nanofillers for compounding	0,07
133	ES 7- Ag packaging	Melt compouding at laboratory scale	0,03
134	ES 6- CNT energy	Professional use (service life) of product containing Li-ion cells with CNTs	0,02
135	ES 7- CNT energy	Consumer use (service life) of product containing Li-ion cells with CNTs	0,02

RANKING OF CONTRIBUTING EXPOSURE SCENARIOS (CES) WITH THE HIGHEST POTENTIAL FOR INHALATION EXPOSURE

Table 27. List of the contributing exposure scenarios (CES) with the highest potential for inhalation exposure.

RANKING	IDENTIFIED USE (IU)	CES - SHORT DESCRIPTION OF PROCESS OR ACTIVITY	SCORE
1	ES 1 - SiO2 electronics	CES 1.4 Packing	396000
2	ES 1- SiO2 concrete	CES 1.4 Packing	396000

3	ES 1 - SiO2 electronics	CE 1.6 Storage and distributrion	343750
4	ES 1- SiO2 concrete	CE 1.6 Storage and distributrion	343750
5	ES 1- SiO2 concrete	CES 1.1. Storage of raw materials	206250
6	ES 1- SiO2 concrete	CES 1.2 synthesis	165000
7	ES 1 - SiO2 electronics	CES 1.1. Storage of raw materials	154688
8	ES 1- SiO2 packaging	CES 1.2. Handling	148500
9	ES 7- cellulose	CES 7.1.collection, sorting and processing	125000
10	ES 4-BaSO4-drilling	CES 4.1. Regular well operation	74453
11	ES 1 - CNT composites&polymers	CES 1.6 Storage and distibution	61875
12	ES 2 - CNT composites&polymers	CES 2.6 Storage and distibution	61875
13	ES 3 - CNT composites&polymers	CES 3.6 Storage and distibution	61875
14	ES 1- CNT energy	CES 1.6 Storage and distibution	61875
15	ES 2- CNT energy	CES 2.6 Storage and distibution	61875
16	ES 3- CNT energy	CES 3.6 Storage and distibution	61875
17	ES 1- SiO2 concrete	CES 1.3 recovery	49500
18	ES 3-BaSO4-drilling	CES 3.2.Mixing with clay and other additives	46533
19	ES 7- SiO2 packaging	CES 7.2. Blending and mixing	41250
20	ES 1 - CNT composites&polymers	CES 1.3 Packing	39600
21	ES 2 - CNT composites&polymers	CES 2.3 Packing	39600
22	ES 3 - CNT composites&polymers	CES 3.3 Packing	39600
23	ES 1- CNT energy	CES 1.3 Packing	39600
24	ES 2- CNT energy	CES 2.3 Packing	39600
25	ES 3- CNT energy	CES 3.3 Packing	39600
26	ES 4- SiO2 electronics	CES 4.1. landfill and soil	38672
27	ES 5 - CNT composites&polymers	CES 5.1 Weighing, mixing, loading	34650
28	ES 2- SiO2 concrete	CES 2.1. Storage of raw materials	34375
29	ES 2- SiO2 electronics	CES 2.1. Storage of raw materials	34375
30	ES 7- SiO2 packaging	CES 7.1. Weighing operations	33000
31	ES 4 - CNT composites&polymers	CES 4.1 Weighing, mixing, loading	25988
32	ES 2-BaSO4-drilling	CES 2.4. Transfer to containers	24840

RANKING OF EXPOSURE SCENARIOS ON THE BASIS OF OCCUPATIONAL DERMAL EXPOSURE SCORES

Table 28. Ranking of exposure scenarios on the basis of occupational dermal exposure scores.

RANKING	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SCORE
1	ES 1 - SiO2 electronics	SiO2 synthesis using : acidification of solutions of sodium silicate, then this gelatinous precipitate is washed and dehydrated	98149
2	ES 1- SiO2 packaging	Manufacturing of Silica NPs by Thermal Decomposition	77803
3	ES 1- SiO2 concrete	SiO2 synthesis using : burning SiCl4 in an oxygen rich hydrocarbon flame to produce a "smoke" SiO2	24151
4	ES 7- cellulose	Recycling and / or disposal	9685
5	ES 1 - CNT composites&polymers	Production/synthesis of CNTs using chemical vapour deposition (CVD)	9503
6	ES 2 - CNT composites&polymers	Production/synthesis of CNT using arc-vapour	9503
7	ES 3 - CNT composites&polymers	Production/synthesis of CNT using laser ablation	9503
8	ES 1- CNT energy	Production/synthesis of CNTs using chemical vapour deposition (CVD)	9503
9	ES 2- CNT energy	Production/synthesis of CNT using arc-vapour	9503
10	ES 3- CNT energy	Production/synthesis of CNT using laser ablation	9503
11	ES 2-BaSO4-drilling	Synthesis of Ba wet route	8059
12	ES 4-BaSO4-plastics, paints and varnish	Formulation of Ba containing plastic starting from powders	7945
13	ES 2-BaSO4-plastics, paints and varnish	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (powder form)	6623
14	ES 2- TiO2 construction	Nano TiO2 synthesis. Sulphate process route	5675
15	ES 1- TiO2 construction	Nano TiO2 synthesis. Chloride process route	5660
16	ES 5 - CNT composites&polymers	Manufacturing of textile fibres	4895
17	ES 2- SiO2 electronics	Manufacturing slurry containing SiO2 NPs	4289
18	ES 1- cellulose	Cellulose synthesis using: i) Extraction from unripe coconut fiber	3533
19	ES 4 - CNT composites&polymers	Manufacturing of intermediate composite materials containing CNTs	3498
20	ES 7 - CNT composites&polymers	Manufacturing of textile products containing CNT fibres	2847
21	ES 1-BaSO4-drilling	Synthesis if Ba dry route	2332
22	ES 2- cellulose	Cellulose synthesis using: ii) Extraction from cotton fibers	2162
23	ES 2- TiO2 textiles	Nano TiO2 synthesis. Production of TiO2 NPs using the wet-chemical process (powder form)	1544
24	ES 4- SiO2 packaging	Formulation solutions with nanomaterials	1540
25	ES 3- TiO2 textiles	Nano TiO2 synthesis. Production of powdered TiO2 NPs using flame spray pyrolysis	1223
26	ES 4- cellulose	Manufacturing of paper - paper by product containing cellulose NPs	1177
27	ES 1- TiO2 paints	Manufacturing of TiO2 nanoparticles by chemical synthesis	1133
28	ES 5- cellulose	Professional Use of biomass	1094
29	ES 6- cellulose	Consumer Use of biomass	1094
30	ES 5- SiO2 packaging	Quality control	896
31	ES 3- SiO2 electronics	Professional use of slurry on electronic wafer	876
32	ES 3- SiO2 packaging	Weighing, bagging and packaging of silica nanospheres	754
33	ES 5-BaSO4-plaStics, paints and varnish	Manufacturing of plastics containing BaSO4 NP	742
34	ES 6-BaSO4-plastics, paints and varnish	Professional Use of plastics containing BaSO4 nanoparticles	728
35	ES 7-BaSO4-plastics, paints and varnish	Consumer Use of plastics containing BaSO4 nanoparticles	728
36	ES 3-BaSO4-plastics, paints and varnish	Formulation of Ba containing plastic starting from liquid dispersion	618
37	ES 2- SiO2 concrete	Manufacturing concrete containing SiO2 NPs	594
38	ES 1-BaSO4-plastics, paints and varnish	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (dispersion form)	530

39	ES 3- cellulose	Manufacturing of biomass/ bio fuel containing cellulose NPs	504
40	ES 5- SiO2 concrete	Recycling and/or disposal	471
41	ES 4- SiO2 electronics	Recycling and/or disposal	425
42	ES 1- TiO2 cosmetics	Manufacturing of cosmetics containing TiO2 NPs (formulation)	384
43	ES 2- TiO2 paints	Weighing, bagging and packaging of silica TiO2 nanoparticles	377
44	ES 6- SiO2 packaging	Cleaning	377
45	ES 1- CeO2 electronics	CeO2 synthesis using : i) low temperature chemical precipitation method	320
46	ES 1- CeO2 paints	CeO2 synthesis using : i) low temperature chemical precipitation method	320
47	ES 7- SiO2 packaging	Preparation of nanofillers for compounding	283
48	ES11 - CNT composites&polymers	Professional use (service life) of concrete products containing CNT	272
49	ES 8- SiO2 packaging	Melt compounding at laboratory scale	266
50	ES 1- ZnO construction	Nano ZnO synthesis. Production of ZnO NPs using the wet-chemical process (powder form)	228
51	ES 6 - CNT composites&polymers	Manufacturing of solid products with composite materials containing CNTs	228
52	ES 8 - CNT composites&polymers	Manufacture of concrete products containing CNTs	216
53	ES 4- SiO2 concrete	consumer use of concrete containing SiO2 NPs	198
54	ES 1 - CeO2 catalyst	CeO2 synthesis using : i) low temperature chemical precipitation method	197
55	ES 2- ZnO construction	Nano ZnO synthesis. Production of powdered ZnO NPs using physical vapor deposition	190
56	ES3 - Ag packaging	Formulating solutions with nanomaterials	163
57	ES12 - CNT composites&polymers	Recycling and disposal of products containing CNTs	141
58	ES 1- TiO2 textiles	Nano TiO2 synthesis. Production of TiO2 NPs using the wet-chemical process (dispersion form)	114
59	ES 1- ZnO paints	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	113
60	ES 5- TiO2 textiles	Functionalization leading to TiO2 nanopowder (starting from liquid dispersion or solid form)	86
61	ES10 - CNT composites&polymers	Professional use (service life) of textile products containing CNT	82
62	ES 1- Ag packaging	Nano Ag synthesis. Production of Ag NPs	78
63	ES 3- TiO2 paints	Manufacturing of intermediates	57
64	ES 5- CeO2 electronics	Recycling and/or disposal	57
65	ES 9 - CNT composites&polymers	Professional use (service life) of solid composite materials containing CNT	54
66	ES 2- CeO2 electronics	Manufacturing electronic devices cotainning CeO2 NPs CeO2 NPs are alo used as a polishing agent in electronic industry	40
67	ES 4- CNT energy	Manufacturing electrode with added MWCNTs	37
68	ES 4- TiO2 textiles	Functionalization leading to TiO2 colloidal solution (starting from liquid dispersion or solid form)	34
69	ES 3- ZnO paints	Manufacturing of intermediates	28
70	ES 5 - CeO2 catalyst	Recycling and/or disposal	28
71	ES 3- ZnO cosmetics	Manufacturing of intermediates	23
72	ES 3- TiO2 construction	Manufacturing of cements containing TiO2 NP	22
73	ES 8- TiO2 textiles	Manufacturing of fibers containing TiO2 NP by Spinning and further manufacturing of functional textiles	21
74	ES 2 - CeO2 catalyst	Manufacturing cataylist cotainning CeO2 NPs	20
75	ES 3- SiO2 concrete	Professional use of concrete containing SiO2 NPs	20
76	ES 9- TiO2 textiles	Professional Use of textiles containing TiO2 nanoparticles	19
77	ES 2- SiO2 packaging	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	17
78	ES 2- Ag textiles	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	15
79	ES 2 - Ag construction	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	15
80	ES 2- Ag electronics	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	15

81	ES 3- CeO2 electronics	Professional use (service life) of electronic devices	12
82	ES 4- CeO2 electronics	Consumer use of electronic devices	12
83	ES 3- Ag textiles	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	12
84	ES 3 - Ag construction	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	12
85	ES 3- Ag electronics	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	12
86	ES 1- Ag cleaning products	Manufacturing of Ag nanoparticles	11
87	ES 5- CeO2 paints	Recycling and/or disposal	9
88	ES 6- TiO2 textiles	Formulation of TiO2 dispersions with other additives (starting from colloidal TiO2 solution or nanopowder form)	9
89	ES 5- CNT energy	Assembly of battery	8
90	ES 7- TiO2 textiles	Manufacturing of textiles containing TiO2 NP by Padding or Exhaustion	8
91	ES 2- CeO2 paints	Manufacturing paints cotainning CeO2 NPs used to provide an UV filter	7
92	ES 1- ZnO cosmetics	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	6
93	ES7- CNT energy	Recycling and disposal of products containing CNTs	5
94	ES 2- Ag packaging	Nano Ag Weighing and bagging	4
95	ES 4- TiO2 paints	Formulation mixing with paints	3
96	ES 4- ZnO construction	Use of cements containing ZnO nanoparticles	2
97	ES 3- Ag cosmetics	Manufacturing of intermediates	2
98	ES 3- CeO2 paints	Professional use of paints cotainning CeO2 NPs	2
99	ES 4- CeO2 paints	Consumer use of paints cotainning CeO2 NPs	2
100	ES 2- ZnO paints	Weighing, bagging and packaging of ZnO nanoparticles	2
101	ES 2- ZnO cosmetics	Weighing, bagging and packaging of ZnO nanoparticles	2
102	ES 5- Ag textiles	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	2
103	ES 3- Ag cleaning products	Manufacturing of intermediates	2
104	ES 1 - Ag textiles	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	1
105	ES 1 - Ag construction	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	1
106	ES 1- Ag electronics	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	1
107	ES 4- TiO2 construction	Use of cements containing TiO2 nanoparticles	1
108	ES 4- ZnO paints	Formulation mixing with paints	1
109	ES 4- Ag textiles	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	1
110	ES 1- Ag cosmetics	Manufacturing of Ag nanoparticles	1
111	ES 4 - CeO2 catalyst	Consumer use of catalyst	1
112	ES 3- ZnO construction	Manufacturing of cements containing ZnO NP	0,48
113	ES 8- Ag textiles	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of functional textiles	0,43
114	ES 9- Ag textiles	Professional Use of textiles containing Ag nanoparticles	0,38
115	ES 5 - Ag construction	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	0,35
116	ES 5- Ag electronics	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	0,35
117	ES 4- Ag packaging	Quality control	0,30
118	ES 4- Ag electronics	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	0,30
119	ES 2- Ag cleaning products	Weighing, bagging and packaging of Ag nanoparticles	0,19
120	ES 2- Ag cosmetics	Weighing, bagging and packaging of Ag nanoparticles	0,19
121	ES 6- Ag textiles	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	0,17
122	ES 7- Ag textiles	Manufacturing of textiles containing Ag NP by Padding or Exhaustion	0,16

123	ES5- Ag packaging	Cleaning	0,15
124	ES 6- Ag electronics	Formulation of Ag ink dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	0,14
125	ES 4 - Ag construction	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	0,14
126	ES 4- ZnO cosmetics	Formulation mixing in cosmetics	0,13
127	ES 8 - Ag construction	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of concretes	0,09
128	ES 9- Ag construction	Biocidal product	0,08
129	ES 10- Ag construction	Coating in building materials	0,08
130	ES 3 - CeO2 catalyst	Professional use of catalyst	0,06
131	ES 4- Ag cleaning products	Formulation mixing with other products	0,04
132	ES 6 - Ag construction	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	0,03
133	ES 7 - Ag construction	Manufacturing of concretes containing Ag NP	0,03
134	ES 6- CNT energy	Professional use (service life) of product containing Li-ion cells with CNTs	0,02
135	ES 7- CNT energy	Consumer use (service life) of product containing Li-ion cells with CNTs	0,02
136	ES 7- Ag electronics	Manufacturing of electronic components containing Ag NPs by Inkjet printing	0,02
137	ES 7- Ag packaging	Melt compouding at laboratory scale	0,01
138	ES 4- Ag cosmetics	Formulation mixing in Health&Personal care and cosmetics	0,01
139	ES 6- Ag packaging	Preparation of nanofillers for compounding	0,01

RANKING OF CONTRIBUTING EXPOSURE SCENARIOS (CES) WITH THE HIGHEST POTENTIAL FOR DERMAL EXPOSURE

Table 29. List of the contributing exposure scenarios (CES) with the highest potential for dermal exposure.

RANKING	IDENTIFIED USE (IU) NAME	CES - SHORT DESCRIPTION OF PROCESS OR ACTIVITY	SCORE
1	ES 1- SiO2 packaging	CES 1.2. Handling	77787
2	ES 1 - SiO2 electronics	CE 1.6 Storage and distributrion	75405
3	ES 1 - CNT composites&polymers	CES 1.6 Storage and distibution	7541
4	ES 2 - CNT composites&polymers	CES 2.6 Storage and distibution	7541
5	ES 3 - CNT composites&polymers	CES 3.6 Storage and distibution	7541
6	ES 1- SiO2 concrete	CES 1.5 Cleaining and maintenance	7541
7	ES 1- CNT energy	CES 1.6 Storage and distibution	7541
8	ES 2- CNT energy	CES 2.6 Storage and distibution	7541
9	ES 3- CNT energy	CES 3.6 Storage and distibution	7541
10	ES 1 - SiO2 electronics	CES 1.3 recovery	7541
11	ES 1 - SiO2 electronics	CES 1.4 Packing	7541
12	ES 1- SiO2 concrete	CE 1.6 Storage and distributrion	7535
13	ES 7- cellulose	CES 7.1.collection, sorting and processing	6855
14	ES 2-BaSO4-drilling	CES 2.4. Transfer to containers	5675
15	ES 1- SiO2 concrete	CES 1.1. Storage of raw materials	3795
16	ES 1- SiO2 concrete	CES 1.4 Packing	3773
17	ES 1 - SiO2 electronics	CES 1.5 Cleaining and maintenance	3773
18	ES 1- TiO2 construction	CES 1.1. Sampling during synthesis and physical separation	3773
19	ES 2- TiO2 construction	CES 2.1. Sampling during synthesis and physical separation	3773
20	ES 2- SiO2 electronics	CES 2.1. Storage of raw materials	3770
21	ES 1 - SiO2 electronics	CES 1.1. Storage of raw materials	2846
22	ES 2-BaSO4-plastics, paints and varnish	CES 2.5. Cleaning and maintenance	2646
23	ES 4-BaSO4-plastics, paints and varnish	CES 4.1. Loading (including weighing and transferring to reactor/tank)	2646
24	ES 4-BaSO4-plastics, paints and varnish	CES 4.5. Cleaning and maintenance	2646
25	ES 4-BaSO4-drilling	CES 4.1. Regular well operation	2269
26	ES 7- cellulose	CES 7.1.collection, sorting and processing	1415
27	ES 7- cellulose	CES 7.1.collection, sorting and processing	1415
28	ES 2-BaSO4-plastics, paints and varnish	CES 2.1. Sampling during synthesis and physical separation	1324
29	ES 2-BaSO4-plastics, paints and varnish	CES 2.2. Drying and grinding processess	1324
30	ES 2-BaSO4-plastics, paints and varnish	CES 2.3. Transfer to containers (including weighing) and packing	1324
31	ES 4-BaSO4-plastics, paints and varnish	CES 4.2. Sampling during formulation	1324
32	ES 4-BaSO4-plastics, paints and varnish	CES 4.3. Discharge from reactor	1324
33	ES 5 - CNT composites&polymers	CES 5.2 Spinning	1321
34	ES 5 - CNT composites&polymers	CES 5.3 Weaving	1321

RANKING OF EXPOSURE SCENARIOS ON THE BASIS OF ENVIRONMENTAL EXPOSURE SCORES

Table 30. Ranking of exposure scenarios on the basis of environmental exposure scores

RANKING	ES	Title	Score
1	ES 1	Cellulose synthesis using: i) Extraction from unripe coconut fiber	3030
2	ES 2	Cellulose synthesis using: ii) Extraction from cotton fibers	3030
3	ES 3	Manufacturing of biomass/ bio fuel containing cellulose NPs	3030
4	ES 4	Manufacturing of paper - paper by product containing cellulose NPs	3030
5	ES 5	Professional Use	3030
6	ES 6	Consumer Use	3030
7	ES 7	Recycling and / or disposal	3030
8	ES 1	SiO2 synthesis using : burning SiCl4 in an oxygen rich hydrocarbon flame to produce a "smoke" SiO2	1667
9	ES 2	Manufacturing concrete containing SiO2 NPs	1667
10	ES 3	Professional use of concrete containing SiO2 NPs	1667
11	ES 4	consumer use of concrete containing SiO2 NPs	1667
12	ES 5	Recycling and/or disposal	1667
13	ES 1	SiO2 synthesis using : acidification of solutions of sodium silicate, then this gelatinous precipitate is washed and dehydrated	1667
14	ES 2	Manufacturing slurry containing SiO2 NPs	1667
15	ES 3	Professional use of slurry on electronic wafer	1667
16	ES 4	Recycling and/or disposal	1667
17	ES 11	Consumer use of cosmetics containing TiO_2 nanoparticles	825
18	ES 1	Manufacturing of cosmetics containing TiO2 NPs (formulation)	167
19	ES 9	Professional Use of textiles containing TiO_2 nanoparticles	110
20	ES 10	Consumer use of textiles containing TiO_2 nanoparticles	110
21	ES 1	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	67
22	ES 2	Weighing, bagging and packaging of ZnO nanoparticles	67
23	ES 1	Nano TiO_2 synthesis. Production of TiO_2 NPs using the wet-chemical process (dispersion form)	61
24	ES 2	Nano TiO_2 synthesis. Production of TiO_2 NPs using the wet-chemical process (powder form)	61
25	ES 3	Nano TiO_2 synthesis. Production of powdered TiO_2 NPs using flame spray pyrolysis	61
26	ES 4	Functionalization leading to TiO_2 colloidal solution (starting from liquid dispersion or solid form)	61
27	ES 5	Functionalization leading to TiO_2 nanopowder (starting from liquid dispersion or solid form)	61
28	ES 7	Manufacturing of textiles containing TiO_2 NP by Padding or Exhaustion	56
29	ES 8	Manufacturing of fibers containing TiO_2 NP by Spinning and further manufacturing of functional textiles	56
30	ES 4	Manufacturing of intermediate composite materials containing CNTs	51
31	ES 1	Production/synthesis of CNTs using chemical vapour deposition (CVD)	48
32	ES 1	Production/synthesis of CNTs using chemical vapour deposition (CVD)	48
33	ES 1	Nano TiO2 synthesis. Chloride process route	36
34	ES 3	Manufacturing of intermediates	28
35	ES 4	Formulation mixing with paints	28
36	ES 2	Nano TiO2 synthesis. Sulphate process route	24
37	ES 1	CeO2 synthesis using : i) low temperature chemical precipitation method	17
38	ES 2	Manufacturing electronic devices cotainning CeO2 NPs. CeO2 NPs are alo used as a polishing agent in electronic industry	17
39	ES 3	Professional use (service life) of electronic devices	17
40	ES 4	Consumer use of electronic devices	17

41	ES 5	Recycling and/or disposal	17
42	ES 1	CeO2 synthesis using : i) low temperature chemical precipitation method	17
43	ES 2	Manufacturing cataylist cotainning CeO2 NPs	17
44	ES 3	Professional use of catalyst	17
45	ES 4	Consumer use of catalyst	17
46	ES 5	Recycling and/or disposal	17
47	ES10	Professional use (service life) of textile products containing CNT	17
48	ES 5	Assembly of battery	15
49	ES 4	Quality control	11
50	ES 5	Cleaning	11
51	ES 5	Cleaning	11
52	ES 6	Preparation of nanofillers for compounding	11
53	ES 2	Production/synthesis of CNT using arc-vapour	9
54	ES 2	Production/synthesis of CNT using arc-vapour	9
55	ES 6	Manufacturing of solid products with composite materials containing CNTs	9
56	ES 1	Nano ZnO synthesis. Production of ZnO NPs using the wet-chemical process (powder form)	6
57	ES 2	Nano ZnO synthesis. Production of powdered ZnO NPs using physical vapor deposition	6
58	ES 4	Manufacturing electrode with added MWCNTs	6
59	ES 8	Recycling and disposal of products containing CNTs	4
60	ES12	Recycling and disposal of products containing CNTs	3
61	ES 3	Production/synthesis of CNT using laser ablation	3
62	ES 3	Production/synthesis of CNT using laser ablation	3
63	ES 6	Formulation of TiO_2 dispersions with other additives (starting from colloidal TiO_2 solution or nanopowder form)	3
64	ES 7	Manufacturing of textile products containing CNT fibres	2
65	ES 8	Manufacture of concrete products containing CNTs	2
66	ES 1	CeO2 synthesis using : i) low temperature chemical precipitation method	2
67	ES 2	Manufacturing paints cotainning CeO2 NPs used to provide an UV filter	2
68	ES 3	Professional use of paints cotainning CeO2 NPs	2
69	ES 4	Consumer use of paints cotainning CeO2 NPs	2
70	ES 5	Recycling and/or disposal	2
71	ES 6	Professional use (service life) of product containing Li-ion cells with CNTs	2
72	ES 7	Consumer use (service life) of product containing Li-ion cells with CNTs	2
73	ES 4	Use as well lubricant	1
74	ES 5	Drilling mud treatment	1
75	ES 9	Professional Use of textiles containing Ag nanoparticles	1
76	ES 10	Consumer use of textiles containing Ag nanoparticles	1
77	ES 9	Professional use (service life) of solid composite materials containing CNT	1
78	ES 1	Synthesis of Ba dry route	1
79	ES 2	Synthesis of Ba wet route	1
80	ES 9	Biocidal product	1
81	ES 10	Coating in building materials	1
82	ES 5	Manufacturing of textile fibres	1
83	ES 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	1
84	ES 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	1
85	ES 3	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	1

86	ES 4	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	1
87	ES 5	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	1
88	ES 1	Manufacturing of TiO2 nanoparticles by chemical synthesis	1
89	ES 2	Weighing, bagging and packaging of silica TiO2 nanoparticles	1
90	ES 1	Manufacturing of Silica NPs by Thermal Decomposition	1
91	ES 2	Filtre removal and particle packaging into vials	1
92	ES 3	Weighing, bagging and packaging of silica nanospheres	1
93	ES 4	Formulation solutions with nanomaterials	1
94	ES 5	Quality control	1
95	ES 1	Nano Ag synthesis. Production of Ag NPs	1
96	ES 2	Nano Ag Weighing and bagging	1
97	ES 1	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	1
98	ES 2	Weighing, bagging and packaging of ZnO nanoparticles	1
99	ES 1	Manufacturing of ZnO nanoparticles	1
100	ES 2	Weighing and bagging	1
101	ES 4	Quality control	1
102	ES 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	1
103	ES 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	1
104	ES 3	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	1
105	ES 4	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	1
106	ES 5	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	1
107	ES 1	Manufacturing of Ag nanoparticles	1
108	ES 2	Weighing, bagging and packaging of Ag nanoparticles	1
109	ES 1	Manufacturing of Ag nanoparticles	1
110	ES 2	Weighing, bagging and packaging of Ag nanoparticles	1
111	ES 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	1
112	ES 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	1
113	ES 3	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	1
114	ES 4	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	1
115	ES 5	Functionalization leading to Ag nanopowder (starting from liquid dispersion or solid form)	1
116	ES 1	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (dispersion form)	1
117	ES 2	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (powder form)	1
118	ES 7	Manufacturing of textiles containing Ag NP by Padding	1
119	ES 8	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of functional textiles	1
120	ES 7	Preparation of nanofillers for compounding	1
121	ES 8	Melt compounding at laboratory scale	1
122	ES 7	Manufacturing of electronic components containing Ag NPs by printing	1
123	ES 5	Manufacturing of plastics, paints and varnish containing BaSO4 NP	1
124	ES 7	Manufacturing of concretes containing Ag NP	0,40
125	ES 8	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of concretes	0,40
126	ES 3	Preparation of drilling fluids	0,36
127	ES11	Professional use (service life) of concrete products containing CNT	0,36
128	ES 3	Formulation of Ba containing plastic, paints or varnish starting from liquid dispersion	0,25
129	ES 4	Formulation of Ba containing plastics, paints or varnish starting from powders	0,25
130	ES 3	Manufacturing of intermediates	0,25

131	ES 4	Formulation mixing with paints	0,25
132	ES 3	Formulating solutions with nanomaterials	0,25
133	ES 3	Manufacturing of intermediates	0,25
134	ES 4	Formulation mixing in cosmetics	0,25
135	ES 3	Formulating solutions with nanomaterials	0,25
136	ES 3	Manufacturing of intermediates	0,17
137	ES 4	Formulation mixing in Health&Personal care and cosmetics	0,17
138	ES 7	Melt compouding at laboratory scale	0,17
139	ES 3	Manufacturing of cements containing ZnO NP	0,14
140	ES 4	Use of cements containing ZnO nanoparticles	0,07
141	ES 6	Professional Use of plastics, paints and varnish containing BaSO4 nanoparticles	0,04
142	ES 3	Manufacturing of intermediates	0,04
143	ES 4	Formulation mixing with other products	0,04
144	ES 6	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	0,03
145	ES 6	Cleaning	0,03
146	ES 6	Preparation of nanofillers for compounding	0,03
147	ES 7	Melt compouding at laboratory scale	0,03
148	ES 6	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	0,03
149	ES 6	Formulation of Ag ink dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	0,02
150	ES 3	Manufacturing of cements containing TiO2 NP	0,02
151	ES 4	Use of cements containing TiO2 nanoparticles	0,02
152	ES 8	Professional use of electronic components containing Ag NPs	0,00
153	ES 9	Consumer use of electronic components containing Ag NPs	0,00

Tables 26 to 30 present a list of the potential tasks where highest exposure is likely to occur. Some trends that can be observed are summarized below:

- On the basis of occupational inhalation exposure, the critical exposure scenarios found to be classified with highest exposure correspond mainly to the synthesis of NPs. The critical steps, under normal operating conditions, are: packing, storage and distribution, weighing and mixing operations.

- On the basis of occupational dermal exposure, the main exposure scenarios correspond, as for inhalation exposure, to the synthesis of NPs, particularly the processes of handling, storage and distribution, recovery, packing and cleaning and maintenance operations.

- On the basis of environmental exposure, exposure scenarios corresponding mainly to the synthesis of NPs are found to be classified with highest exposure.

In summary, the scenarios with the highest worker exposure to the core set of nanoparticles along the life cycle of nanoproducts are distinguished in four general source domains:

1- ENM synthesis, examples of production processes such as chemical vapour condensation, arc-vapour, laser ablation, thermal decomposition or flame spray pyrolisis
2- Handling and transfer of bulk powdered MNOs (e.g weighing, bagging, mixing or packaging of powder)
3- Manufacturing of intermediate materials containing ENM
4- Cleaning and maintenance processes

Critical task activities involving nanomaterials which require special attention, under normal operating conditions, when assessing exposure include:

- Weighing and mixing operations (transfer tasks)
- Handling particulate nanomaterials, storage and distribution
- Recovery and packing
- Cleaning and maintenance operations

These rankings for exposure potential can be used to select scenarios for other tasks in WP3. It should be kept in mind that this task did not address the accidental exposure scenarios, and that is focused on normal operation conditions that are most likely to cause harm. Moreover, the assessment should be always reported and reviewed if circumstances change or more accurate data becomes available.

In the case of lack of data, the precautionary principle, a conservative approach, was used, which leads to the overestimation of the exposure, and may have reduced the ability to discriminate among tasks with different exposure potential. It should be also mentioned that by implementing correct organizational procedures (risk management measures); exposure scenarios may decrease the risks from a high risk to medium/low risk scenarios.

3 Deviations from the work plan

The main reasons for the deviations in the timelines for this deliverable are related to the delays on selecting core ENMs for the NANoREG project, and the late submission by some of the partners of their input. The present document will be considered as the final version of the deliverable.

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5 Annexes

Annex I. Life cycle maps

Annex II. Identification of generic exposure scenarios

Annex III. Exposure scores assignment to different PROCs.

Annex IV. Use maps for the prioritization of exposure scenarios

Annex V. Template suggestion for exposure scenario description

ANNEX I - LIFE CYCLE MAPS

This annex shows the life cycle maps developed throughout the project

Figure A1. Life cycle map for TiO_2 nanoparticles in cosmetics.

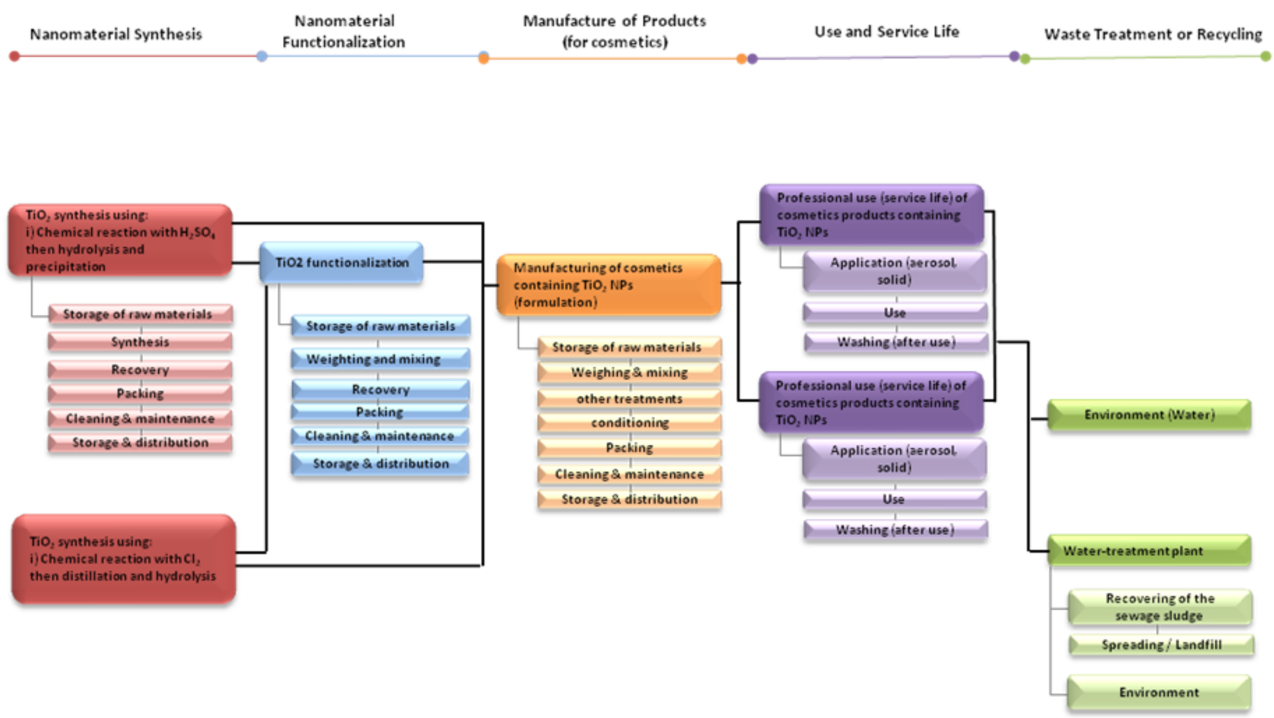


Figure A2. Life cycle map for TiO_2 nanoparticles in textiles.

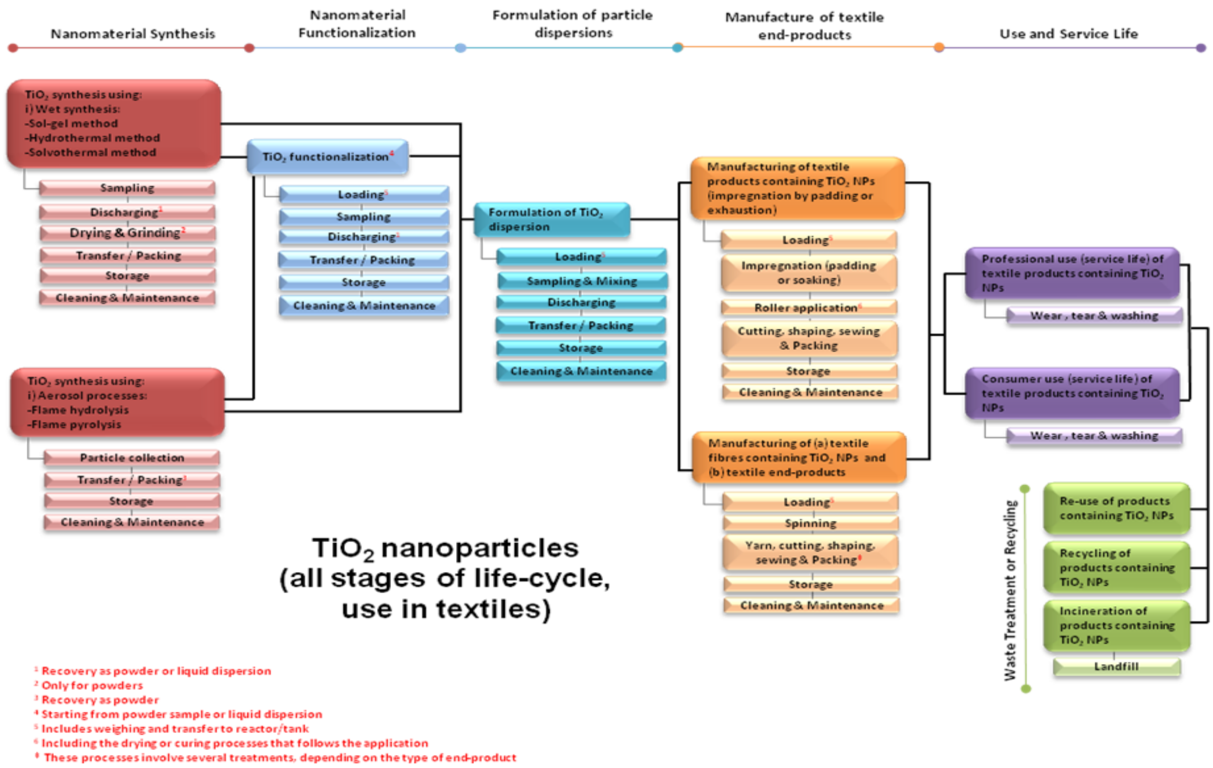


Figure A3. Life cycle map for SiO_2 nanoparticles in construction.

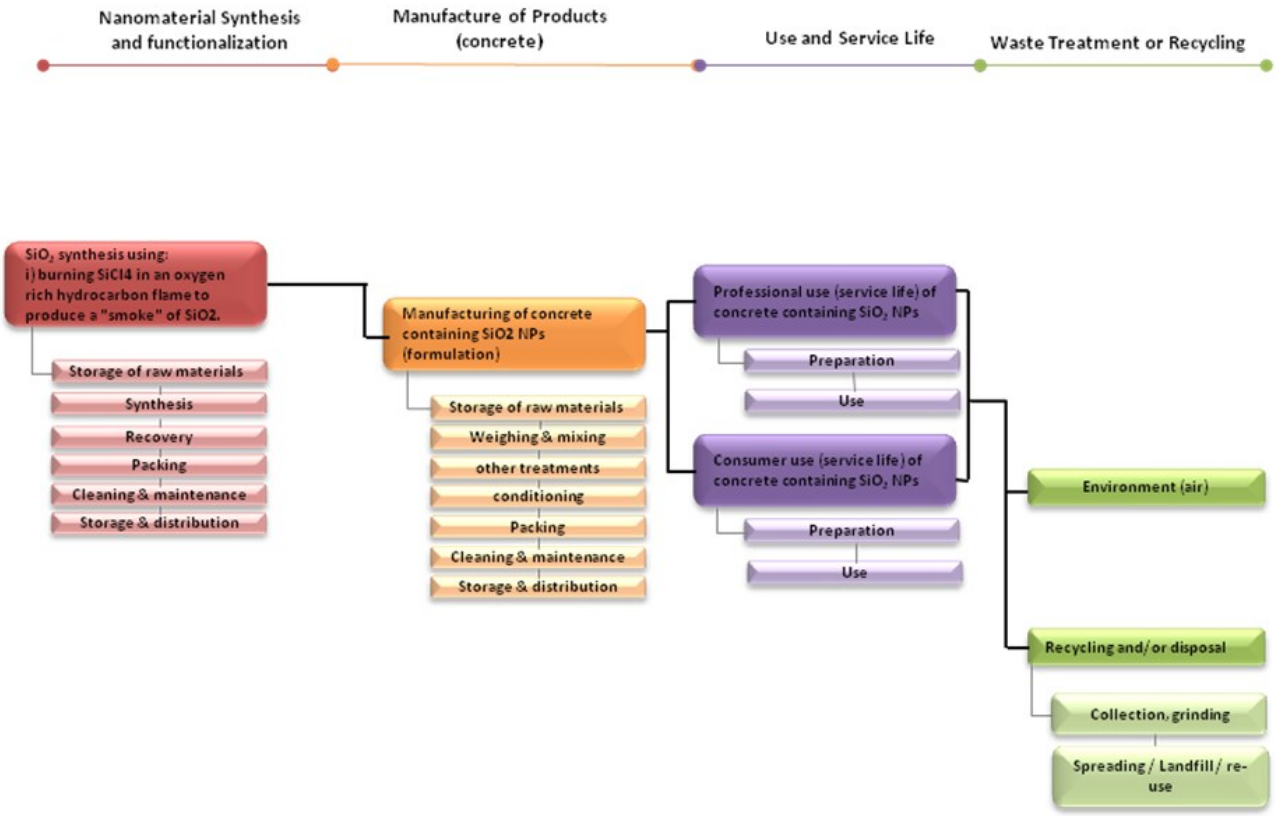


Figure A4. Life cycle map for SiO_2 nanoparticles in electronics.

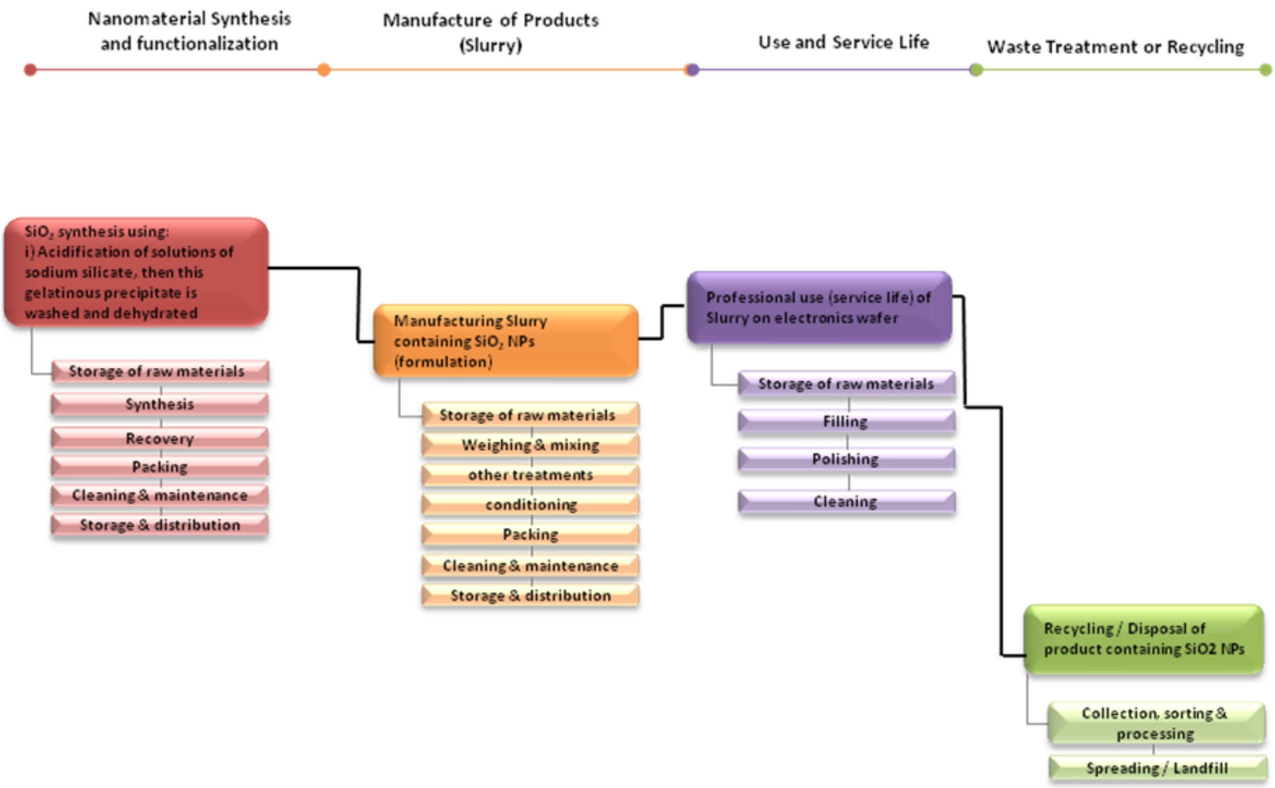


Figure A5. Life cycle map for CeO_2 nanoparticles in electronics.

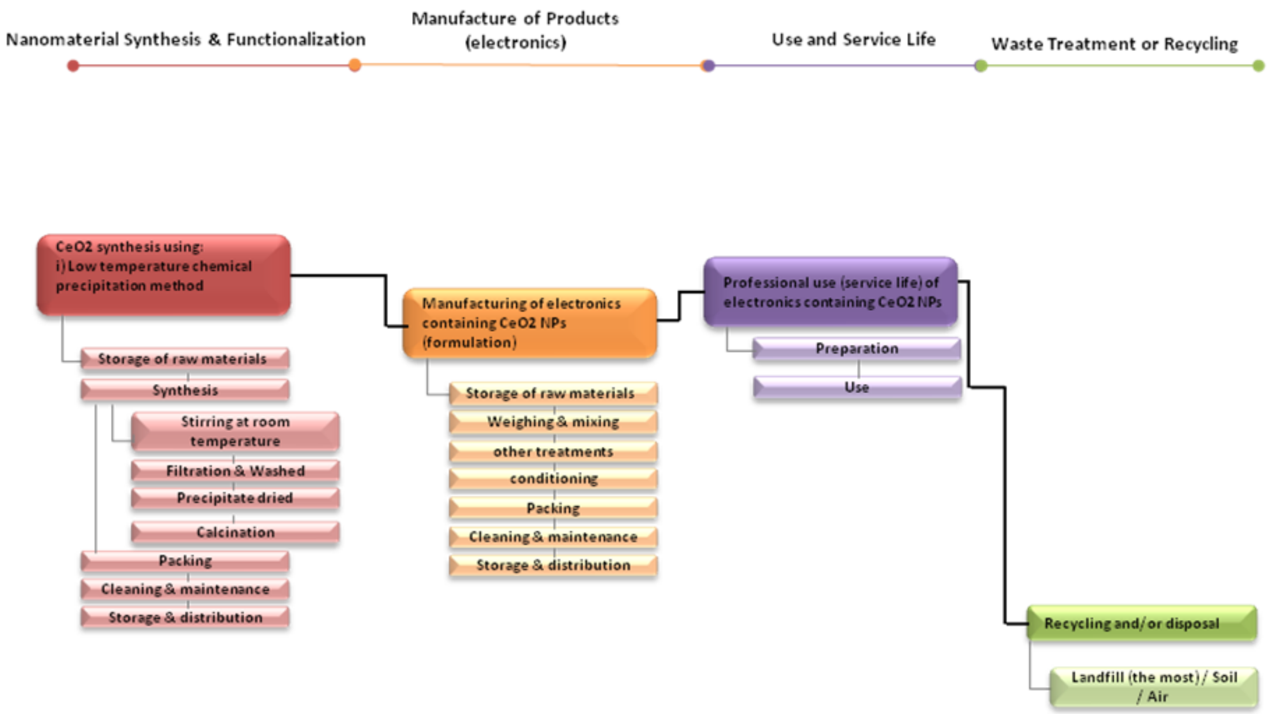


Figure A6. Life cycle map for CeO_2 nanoparticles in fuel catalyst.

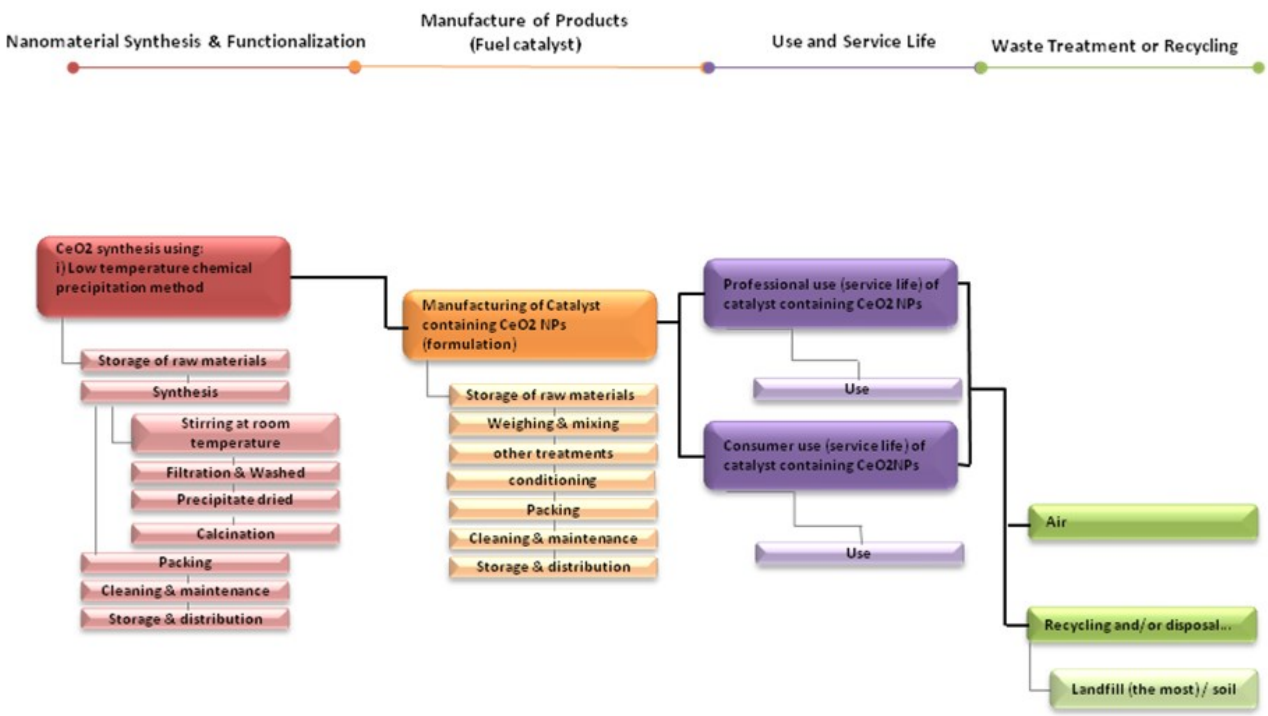


Figure A7. Life cycle map for CeO_2 nanoparticles in coatings and paints.

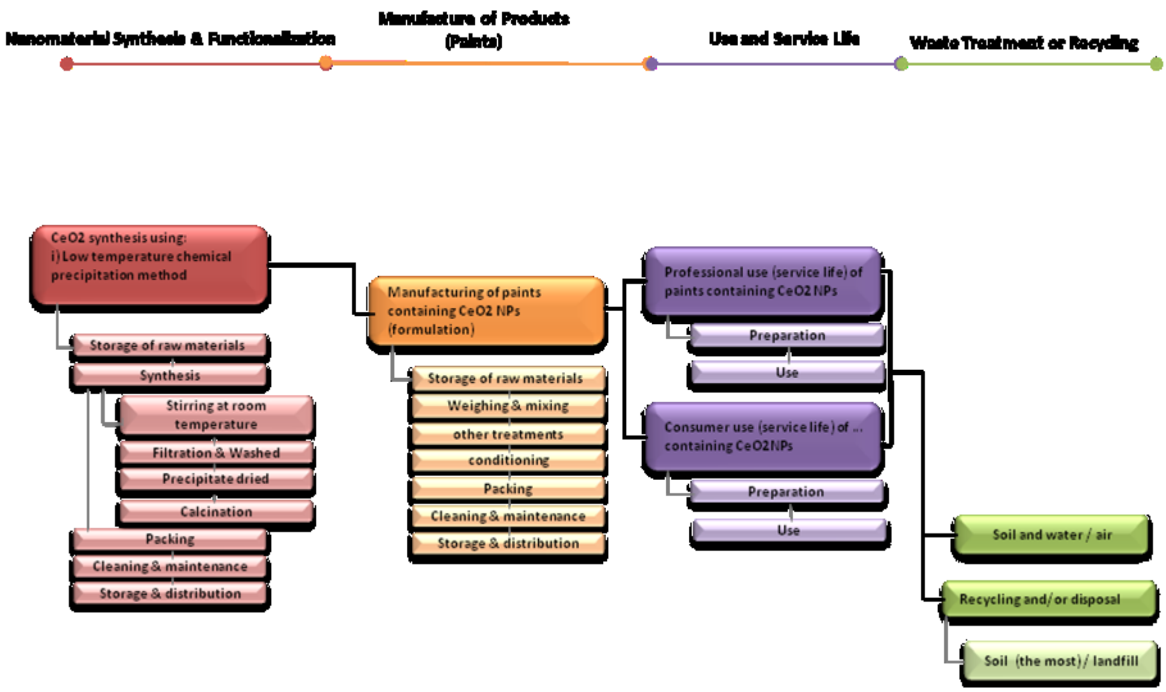


Figure A8. Life cycle map for nanocellulose in paper & paper board.

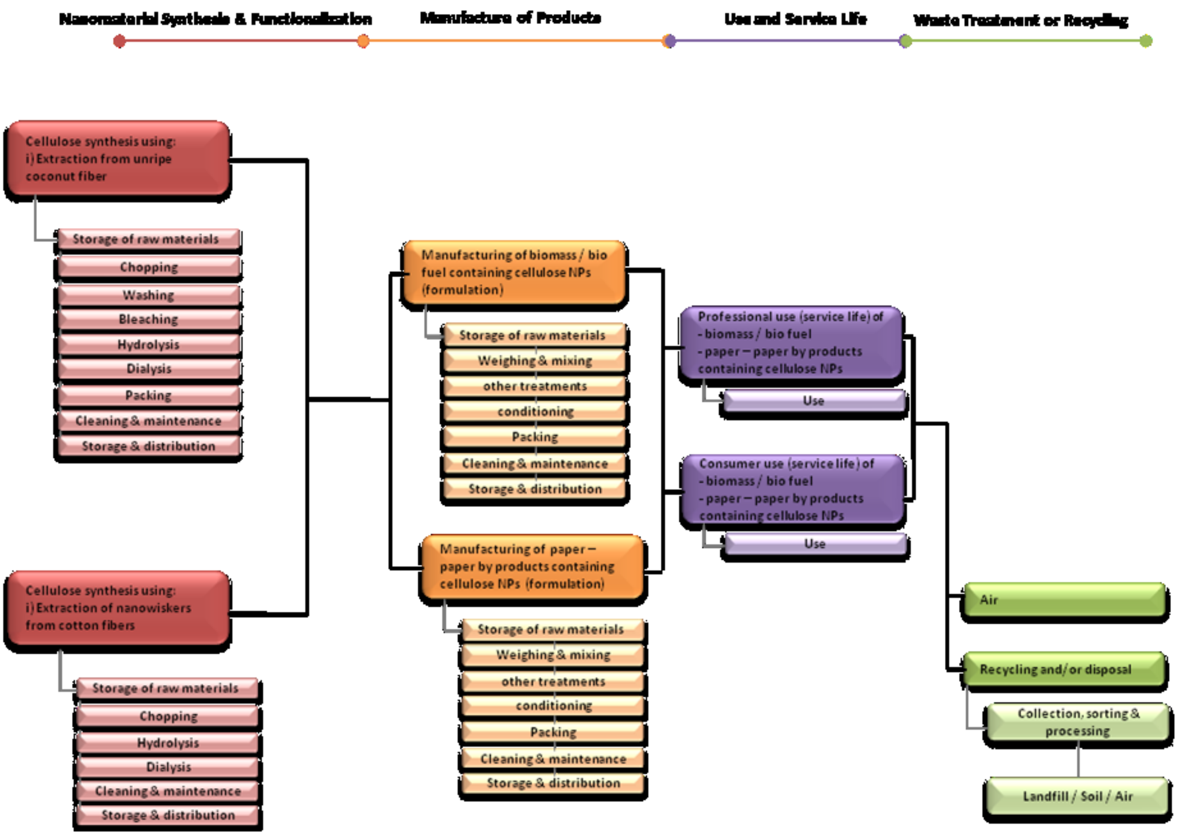


Figure A9. Life cycle map for CNT in composites.

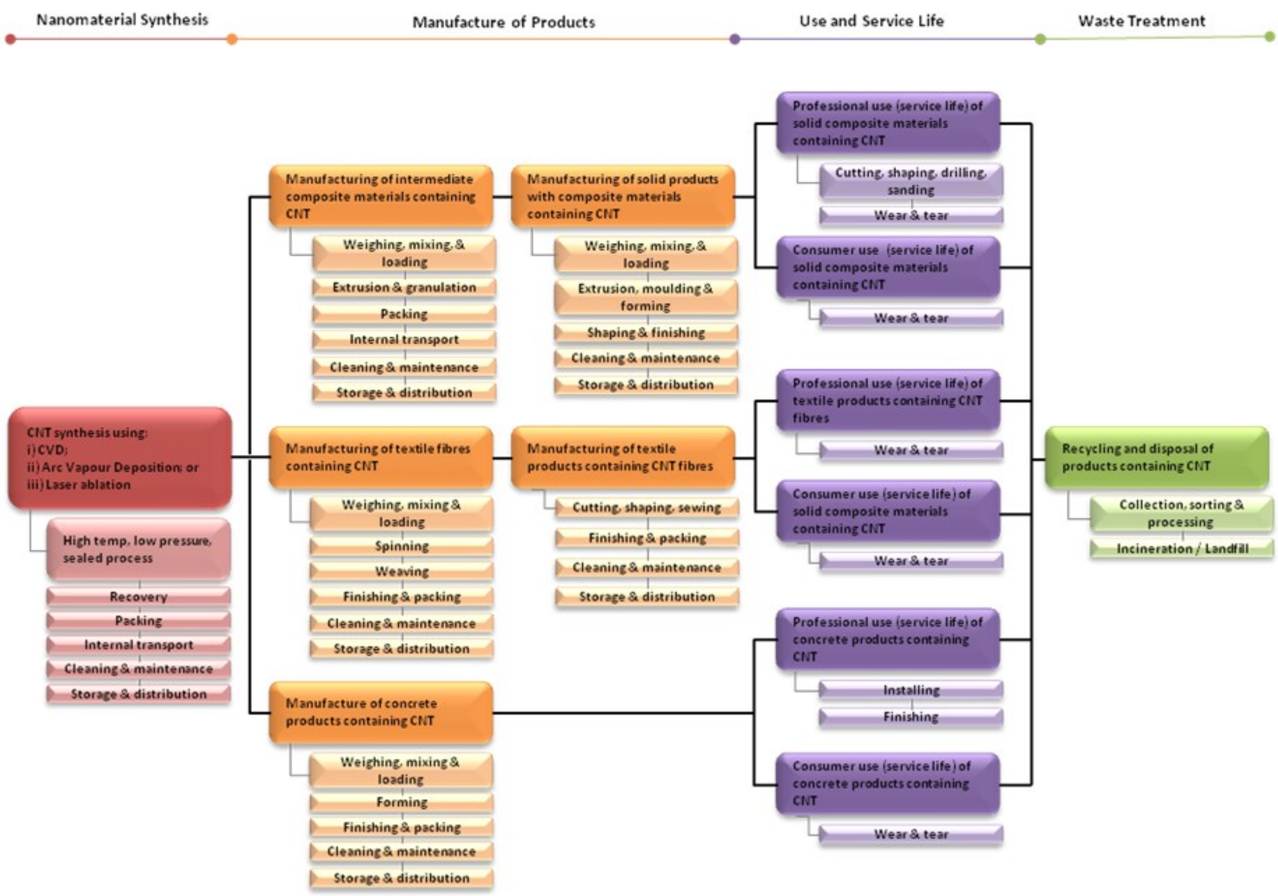


Figure A10. Life cycle map for Ag nanoparticles in electronics

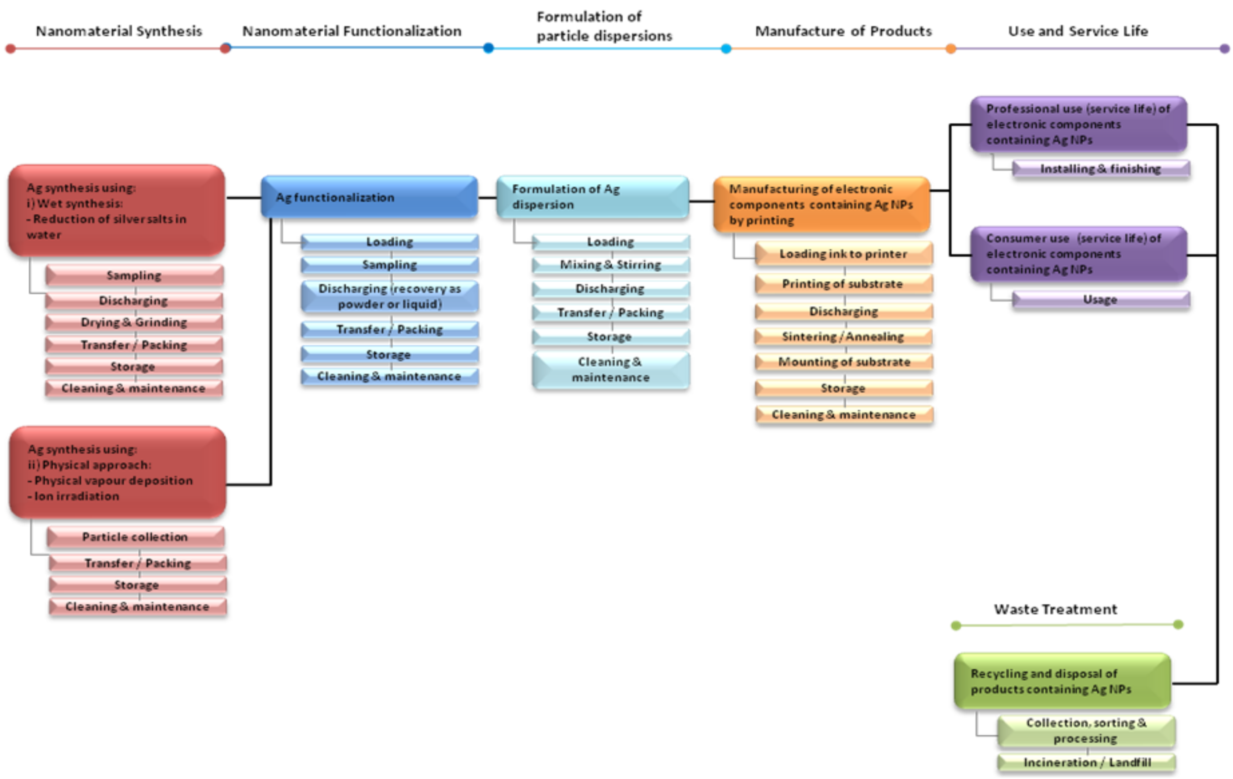


Figure A11. Life cycle map for CNT nanoparticles in energy applications

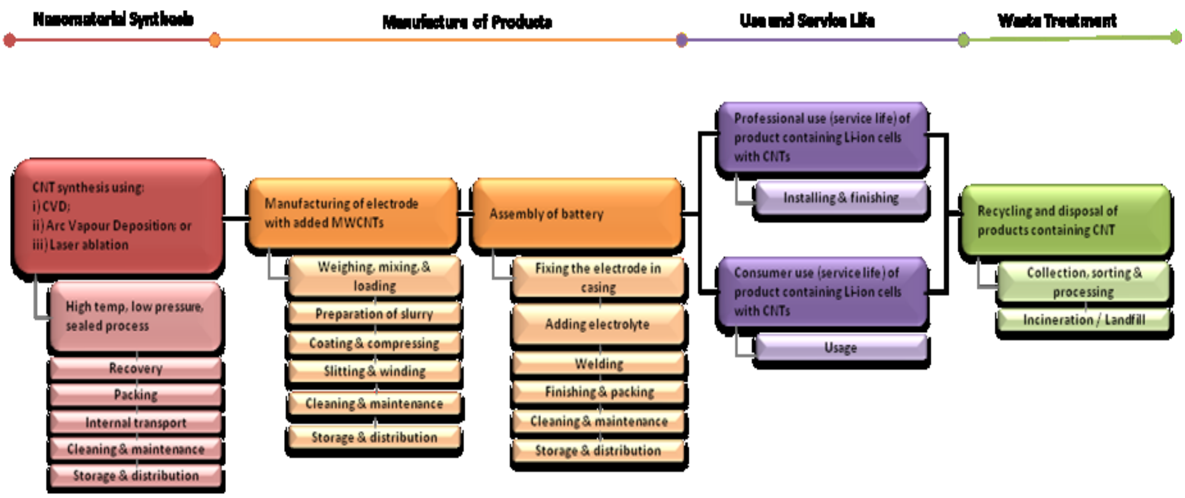


Figure A12. Life cycle map for $BaSO_4$ nanoparticles in polymer applications

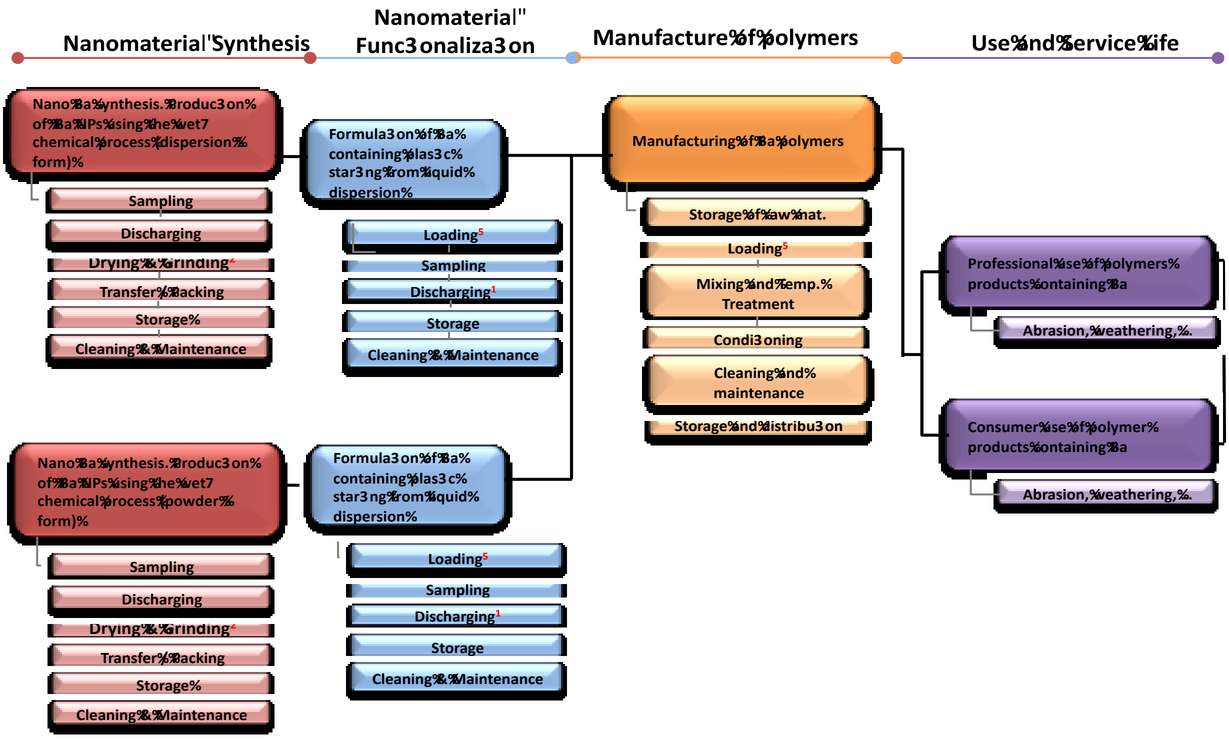
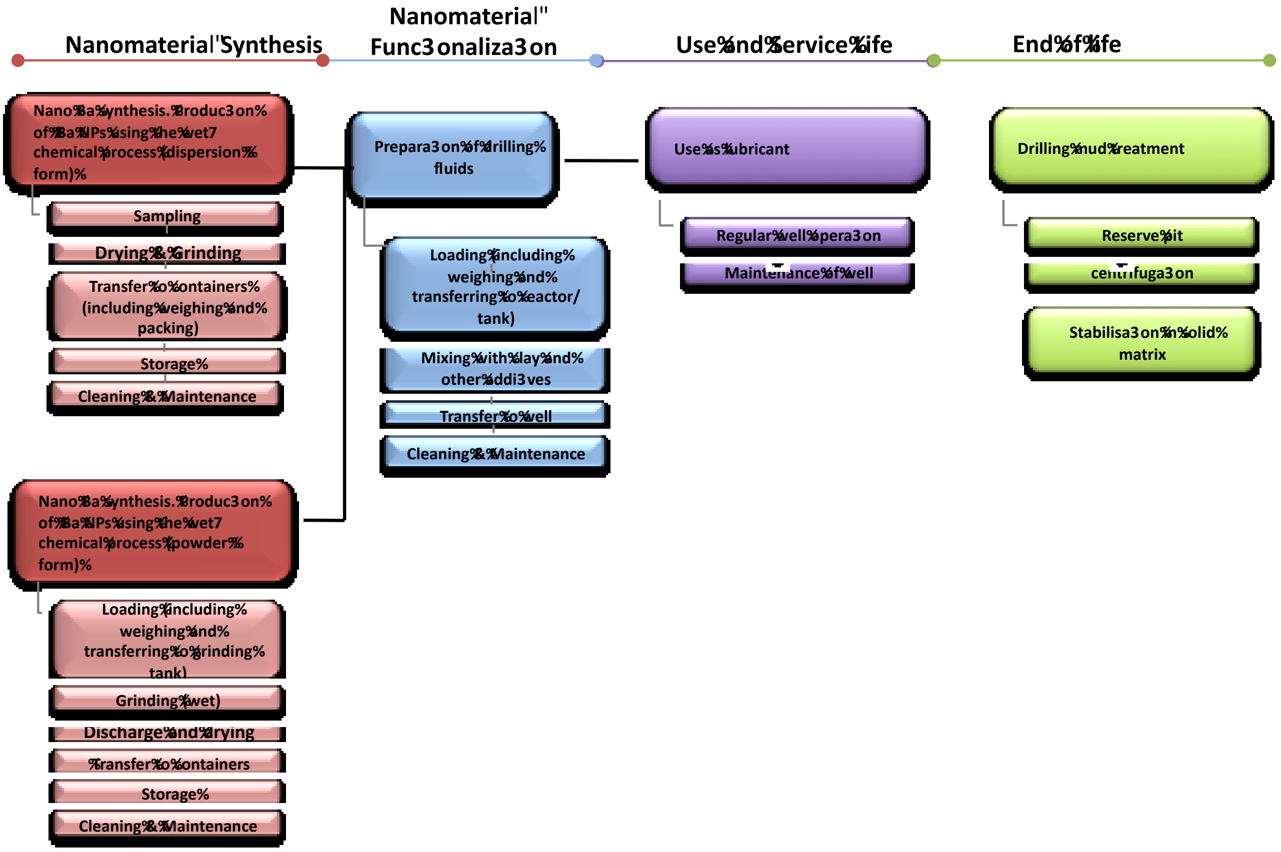


Figure A13 Life cycle map for $BaSO_4$ nanoparticles in drilling applications



ANNEX II - IDENTIFICATION OF GENERIC EXPOSURE SCENARIOS (GES)

This Annex shows the GES and CES identified for each use for the core set of nanoparticles selected for the NANoREG project.

Table A1. List of GES identified for nano Ag in textiles

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES Ag 1 (Nano Ag synthesis)	ES 1	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (dispersion form)	CES 1.1. Sampling during synthesis
			CES 1.2. Discharge from reactor/tank
			CES 1.3. Transfer to small containers (including weighing) and packing
			CES 1.4. Storage
			CES 1.5. Cleaning and maintenance
	ES 2	Nano Ag synthesis. Production of Ag NPs using the wet-chemical process (powder form)	CES 2.1. Sampling during synthesis and physical separation
			CES 2.2. Drying and grinding processess
			CES 2.3. Transfer to small containers (including weighing) and packing
			CES 2.4. Storage
			CES 2.5. Cleaning and maintenance
	ES 3	Nano Ag synthesis. Production of powdered Ag NPs using physical vapor deposition	CES 3.1. Synthesis (including collection of particles)
			CES 3.2.Transfer to small containers (including weighing) and packing
			CES 3.3. Storage
			CES 3.4. Cleaning and maintenance
GES Ag 2 (Ag Functionalization)	ES 4	Functionalization leading to Ag colloidal solution (starting from liquid dispersion or solid form)	CES 4.1. Loading (including weighing and transferring to reactor/tank)
			CES 4.2. Sampling during functionalization
			CES 4.3. Discharge from reactor/tank
			CES 4.4. Transfer to small containers (including weighing) and packing
			CES 4.5. Storage
			CES 4.6. Cleaning and maintenance
	ES 5	Functionalization leading to Ag nanopowder (starting	CES 5.1. Loading (including weighing and transferring to reactor/tank)

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
		from liquid dispersion or solid form)	CES 5.2. Sampling during functionalization
			CES 5.3. Drying and grinding processess
			CES 5.4. Transfer to small containers (including weighing) and packing
			CES 5.5. Storage
			CES 5.6. Cleaning and maintenance
GES Ag 3 (Formulation of Ag dispersion)	ES 6	Formulation of Ag dispersions with other additives (starting from colloidal Ag solution or nanopowder form)	CES 6.1. Loading (including weighing and transferring to reactor/tank)
			CES 6.2. Mixing and sampling
			CES 6.3. Discharge from reactor/tank
			CES 6.4. Transfer to small containers (including weighing) and packing
			CES 6.5. Storage
			CES 6.6. Cleaning and maintenance
GES Ag 4 (Manufacturing of textiles containing Ag NPs)	ES 7	Manufacturing of textiles containing Ag NP by Padding or Exhaustion	CES 7.1. Loading (including weighing and transferring to reactor/tank)
			CES 7.2. Padding or soaking (impreganation treatments)
			CES 7.3. Roller application (including drying and curing processes that follows)
			CES 7.4. Cutting, shaping, sewing and packing. Textile manipulation
			CES 7.5. Storage
			CES 7.6. Cleaning and maintenance
	ES 8	Manufacturing of fibers containing Ag NP by Spinning and further manufacturing of functional textiles	CES 8.1. Loading (including weighing, mixing and transferring)
			CES 8.2. Spinning
			CES 8.3. Yarn, cutting, shaping, sewing and packing. Textile manipulation
			CES 8.4. Storage
			CES 8.5. Cleaning and maintenance
GES Ag 5 (use)	ES 9	Professional Use of textiles containing Ag nanoparticles	CES 9.1. Usage (wearing)
			CES 9.2. Washing
	ES 10	Consumer use of textiles containing Ag nanoparticles	CES 10.1. Usage (wearing)
			CES 10.2. Washing

Table A2. List of GES identified for nano TiO_2 in cosmetics and textiles

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES TiO_2 1 (Nano TiO2 synthesis)	ES 1	Nano TiO2 synthesis. Production of TiO2 NPs using the wet-chemical process (dispersion form)	CES 1.1. Sampling during synthesis
			CES 1.2. Discharge from reactor/tank
			CES 1.3. Transfer to small containers (including weighing) and packing
			CES 1.4. Storage
			CES 1.5. Cleaning and maintenance
	ES 2	Nano TiO2 synthesis. Production of TiO2 NPs using the wet-chemical process (powder form)	CES 2.1. Sampling during synthesis and physical separation
			CES 2.2. Drying and grinding processess
			CES 2.3. Transfer to small containers (including weighing) and packing
			CES 2.4. Storage
			CES 2.5. Cleaning and maintenance
	ES 3	Nano TiO2 synthesis. Production of powdered TiO2 NPs using physical vapor deposition	CES 3.1. Synthesis (including collection of particles)
			CES 3.2.Transfer to small containers (including weighing) and packing
			CES 3.3. Storage
			CES 3.4. Cleaning and maintenance
GES TiO2 2 (TiO2 Functionalization)	ES 4	Functionalization leading to TiO2 colloidal solution (starting from liquid dispersion or solid form)	CES 4.1. Loading (including weighing and transferring to reactor/tank)
			CES 4.2. Sampling during functionalization
			CES 4.3. Discharge from reactor/tank
			CES 4.4. Transfer to small containers (including weighing) and packing
			CES 4.5. Storage
			CES 4.6. Cleaning and maintenance
	ES 5	Functionalization leading to TiO2 nanopowder (starting from liquid dispersion or solid form)	CES 5.1. Loading (including weighing and transferring to reactor/tank)
			CES 5.2. Sampling during functionalization
			CES 5.3. Drying and grinding processess

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
			CES 5.4. Transfer to small containers (including weighing) and packing
			CES 5.5. Storage
			CES 5.6. Cleaning and maintenance
GES TiO2 3 (Formulation of TiO2 dispersion)	ES 6	Formulation of TiO2 dispersions with other additives (starting from colloidal TiO2 solution or nanopowder form)	CES 6.1. Loading (including weighing and transferring to reactor/tank)
			CES 6.2. Mixing and sampling
			CES 6.3. Discharge from reactor/tank
			CES 6.4. Transfer to small containers (including weighing) and packing
			CES 6.5. Storage
			CES 6.6. Cleaning and maintenance
GES TiO2 4 (Manufacturing of textiles containing TiO2 NPs)	ES 7	Manufacturing of textiles containing TiO2 NP by Padding or Exhaustion	CES 7.1. Loading (including weighing and transferring to reactor/tank)
			CES 7.2. Padding or soaking (impreganation treatments)
			CES 7.3. Roller application (including drying and curing processes that follows)
			CES 7.4. Cutting, shaping, sewing and packing. Textile manipulation
			CES 7.5. Storage
			CES 7.6. Cleaning and maintenance
	ES 8	Manufacturing of fibers containing TiO2 NP by Spinning and further manufacturing of functional textiles	CES 8.1. Loading (including weighing, mixing and transferring)
			CES 8.2. Spinning
			CES 8.3. Yarn, cutting, shaping, sewing and packing. Textile manipulation
			CES 8.4. Storage
			CES 8.5. Cleaning and maintenance
GES TiO2 5 (use)	ES 9	Professional Use of textiles containing TiO2 nanoparticles	CES 9.1. Usage (wearing)
			CES 9.2. Washing
	ES 10	Consumer use of textiles containing TiO2 nanoparticles	CES 10.1. Usage (wearing)
			CES 10.2. Washing
GES TiO2 6 (use)	ES 11	Professional Use of cosmetics containing TiO2 nanoparticles	CES 11.1. Application (aerosols)
			CES 11.2. Use
			CES 11.3. Washing (after use)
	ES 12	Consumer use of cosmetics containing TiO2 nanoparticles	CES 12.1. Application (aerosols)
			CES 12.2. Use
			CES 12.3. Washing (after use)

Table A3. List of GES identified for nano SiO_2 in construction

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
SiO2	ES1	SiO2 burning SiCl4 in an oxygen rich hydrocarbon flame to produce a "smoke" SiO2	Storage of raw materials
			Synthesis
			Recovery
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES2	Manufacturing concrete containing SiO2 NPs	Storage of raw materials
			Weighing & Mixing
			Other treatments
			Conditioning
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES3	Profession/al use of concrete	Storage of raw materials
			Preparation
			Use
	ES4	Consumer use of concrete	Storage of raw materials
			Preparation
			Use

Table A4. List of GES identified for nano SiO_2 in electronics

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
SiO2	ES1	SiO2 synthesis using: i) Acidification of solutions of sodium silicate, then this gelatinous precipitate is washed and dehydrated	Storage of raw materials
			Synthesis
			Recovery
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES2	Manufacturing slurry containing SiO2 NPs	Storage of raw materials
			Weighing & Mixing
			Other treatments
			Conditioning
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES3	Profession/al use of slurry on electronics wafer	Storage of raw materials
			Filling
			Polishing
			Cleaning & Maintenance

Table A5. List of GES identified for nanocellulose in paper

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
Cellulose	ES1	Cellulose synthesis using: i) Extraction from unripe coconut fiber	Storage of raw materials
			Chopping
			Washing
			Bleaching
			Hydrolysis
			Dialysis
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES2	Cellulose synthesis using: i) Extraction from cotton fibers	Storage of raw materials
			Chopping
			Hydrolysis
			Dialysis
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES3	Manufacturing of biomass / bio fuel containing cellulose NPs	Storage of raw materials
			Weighing & Mixing
			Other treatments
			Conditioning
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES4	Manufacturing of paper - paper by products containing cellulose NPs	Storage of raw materials
			Weighing & Mixing
			Other treatments

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
			Conditioning
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES5	Professional use of biomass …	use
		Professional use of paper …	use
	ES6	Consumer use of biomass …	use
		Consumer use of paper …	use
	ES7	Recycling and/or disposal	collection, sorting and processing

Table A6. List of GES identified for nano CeO_2 in fuel catalyst

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
CeO2	ES1	CeO2 synthesis using: i) Low temperature chemical precipitation method	Storage of raw materials
			Synthesis
			Stirring at room temperature
			Filtration & Washed
			Precipitate dried
			Calcination
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES2	Manufacturing catalyst containing CeO2 NPs	Storage of raw materials
			Weighing & Mixing
			Other treatments
			Conditioning
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES3	Professional use of catalyst	use
	ES4	Consumer use of caralyst	use
	ES5	Recycling and/or disposal	landfill (the most) / soil

Table A7. List of GES identified for nano CeO_2 in electronics

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
CeO2	ES1	CeO2 synthesis using: i) Low temperature chemical precipitation method	Storage of raw materials
			Synthesis
			Stirring at room temperature
			Filtration & Washed
			Precipitate dried
			Calcination
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES2	Manufacturing electronic devices containing CeO2 NPs CeO2 NPs is also use as a polishing agent in electronic industry	Storage of raw materials
			Weighing & Mixing
			Other treatments
			Conditioning
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES3	Professional use of electronics device	preparation
			use
	ES5	Recycling and/od disposal	landfill (the most) / soil/ air

Table A8. List of GES identified for nano CeO_2 in coatings and paints

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
CeO2	ES1	CeO2 synthesis using: i) Low temperature chemical precipitation method	Storage of raw materials
			Synthesis
			Stirring at room temperature
			Filtration & Washed
			Precipitate dried
			Calcination
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES2	Manufacturing paints containing CeO2 NPs It is use to provide an UV filter	Storage of raw materials
			Weighing & Mixing
			Other treatments
			Conditioning
			Packing
			Cleaning & Maintenance
			Storage & Distribution
	ES3	Professional use of paints	preparation
			use
	ES4	Consumer use of paints	preparation
			use
	ES5	Recycling and/or disposal	Landfill (the most) / soil / air

Table A9. List of GES identified for CNT in composites

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITTLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
CNT synthesis	ES1	Production/synthesis of CNTs using chemical vapour deposition (CCD)	1.1 synthesis
			1.2 recovery
			1.3 packing
			1.4 internal transport
			1.5 cleaning & maintenance
			1.6 storage & distribution
	ES2	Production/synthesis of CNTs using arc-vapour	2.1 synthesis
			2.2 recovery
			2.3 packing
			2.4 internal transport
			2.5 cleaning & maintenance
			2.6 storage & distribution
	ES3	Production/synthesis of CNTs using laser oven	3.1 synthesis
			3.2 recovery
			3.3 packing
			3.4 internal transport
			3.5 cleaning & maintenance
			3.6 storage & distribution
Manufacturing of intermediate CNT products	ES4	Manufacturing of intermediate composite materials containing CNT	4.1 weighing, mixing & loading
			4.2 extrusion & granulation
			4.3 packing
			4.4 internal transport
			4.5 cleaning & maintenance
			4.6 storage & distribution
	ES5	Manufacturing of textile fibres containing CNT	5.1 weighing, mixing & loading
			5.2 spinning
			5.3 weaving
			5.4 finishing & packing
			5.5 cleaning & maintenance
			5.6 storage & distribution
Manufacturing of products containing CNT	ES6	Manufacturing of solid products with composite materials containing CNT	6.1 weighing, mixing & loading
			6.2 extrusion, moulding & forming
			6.3 shaping & finishing
			6.4 cleaning & maintenance
			6.6 storage & distribution
	ES7	Manufacturing of textile products containing CNT	7.1 cutting, shaping, sewing
			7.2 finishing & packing

		fibres	7.3 cleaning & maintenance
			7.4 storage & distribution
	ES8	Manufacture of concrete products containing CNT	8.1 weighing, mixing & loading
			8.2 forming
			8.3 finishing & packing
			8.4 cleaning & maintenance
			8.5 storage & distribution
Use and service life	ES9	Professional use (service life) of solid composite materials containing CNT	9.1 cutting, shaping, drilling, sanding
			9.2 wear & tear
	ES10	Consumer use (service life) of solid composite materials containing CNT	10.1 wear & tear
	ES 11	Professional use (service life) of textile products containing CNT fibres	11.1 wear & tear
	ES 12	Consumer use (service life) of textile products containing CNT fibres	12.1 wear & tear
	ES 13	Professional use (service life) of concrete products containing CNT	13.1 installing
			13.2 finishing
	ES 14	Consumer use (service life) of concrete products containing CNT	14.1 wear & tear
Waste treatment	ES 15	Recycling and disposal of products containing CNT	15.1 collection, sorting & processing
			15.2 incineration/ landfill

Table A10. List of GES identified for nano Ag in packaging

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES Ag 1	ES 1	Manufacturing of Ag nanoparticles	Handling
GES Ag 1	ES 2	Weighing and bagging	Weighing, bagging and packaging of silica NPs
GES Ag 2	ES 3	Formulating solutions with nanomaterials	Weighing
GES Ag 2	ES 3	Formulating solutions with nanomaterials	Blending and mixing
GES Ag 2	ES 3	Formulating solutions with nanomaterials	Filling
GES Ag 2	ES 4	Quality control	Weighing
GES Ag 2	ES 4	Quality control	Bagging and mixing
GES Ag 2	ES 5	Cleaning	Cleaning and maintenance
GES SiO2 3	ES6	Preparation of nanofillers for compounding	Weighing operations
GES SiO2 3	ES6	Preparation of nanofillers for compounding	Blending and mixing
GES SiO2 3	ES7	Melt compouding at laboratory scale	Feeding phase
GES SiO2 3	ES7	Melt compouding at laboratory scale	Extrusion
GES SiO2 3	ES7	Melt compouding at laboratory scale	Cutting
GES SiO2 3	ES7	Melt compouding at laboratory scale	Cleaning and maintenance of the extruder

Table A11. List of GES identified for nano CeO_2 in packaging

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES CeO2 1	ES1	Manufacturing of CeO2 nanoparticles	Handling
	ES 2	Weighing and bagging	Weighing, bagging and packaging of CeO2 nanoparticles
GES CeO2 2	ES 3	Formulating solutions with nanomaterials	Weighing
			Blending and mixing
			Filling
	ES 4	Quality control	Weighing
			Bagging and mixing
	ES 5	Cleaning	Cleaning and maintenance
GES CeO2 3	ES6	Preparation of nanofillers for compounding	Weighing operations
			Blending and mixing
	ES7	Melt compouding at laboratory scale	Feeding phase
			Extrusion
			Cutting
			Cleaning and maintenance of the extruder

Table A12. List of GES identified for nano SiO_2 in packaging

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES SiO2 1	ES 1	Manufacturing of Silica NPs by Thermal Decomposition	Synthesis by thermal decomposition
			Handling
	ES 2	Manufacturing of Silica NPs by Spray Flame Pyrolysis	Filter removal and particle packaging into vials
	ES 3	Weighing, bagging and packaging of silica nanospheres	Weighing, bagging and packaging of silica NPs
GES SiO2 2	ES 4	Formulating solutions with nanomaterials	Weighing
			Blending and mixing
			Filling
	ES 5	Quality control	Weighing
			Bagging and mixing
	ES 6	Cleaning	Cleaning and maintenance
GES SiO2 3	ES7	Preparation of nanofillers for compounding	Weighing operations
			Blending and mixing
	ES8	Melt compounding at laboratory scale	Feeding phase
			Extrusion
			Cutting
			Cleaning and maintenance of the extruder

Table A13. List of GES identified for nano TiO_2 in paints

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES TiO2 1	ES 1	Manufacturing of TiO2 nanoparticles by chemical synthesis	Synthesis by chemical synthesis
			Handling
			Cleaning and maintenance
	ES 2	Weighing, bagging and packaging of silica TiO2 nanoparticles	Weighing, bagging and packaging of TiO2 nanoparticles
GES TiO2 2	ES 3	Manufacturing of intermediates	Weighing
			Blending and mixing
			Cleaning and maintenance
GES TiO2 3	ES4	Formulation mixing with paints	Blending and mixing

Table A14. List of GES identified for nano ZnO in cosmetics

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES ZnO 1	ES 1	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	Synthesis by chemical synthesis
			Handling
			Cleaning and maintenance
	ES 2	Weighing, bagging and packaging of ZnO nanoparticles	Weighing, bagging and packaging of Nanoparticles
GES ZnO 2	ES 3	Manufacturing of intermediates	Weighing
			Blending and mixing
			Cleaning and maintenance
GES ZnO 3	ES4	Formulation mixing with paints	Blending and mixing

Table A15. List of GES identified for nano ZnO in packaging

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES ZnO 1	ES1	Manufacturing of ZnO nanoparticles	Synthesis by flame spray pirolisis
			Handling
	ES 2	Weighing and bagging	Weighing, bagging and packaging of ZnO nanoparticles
GES ZnO 2	ES 3	Formulating solutions with nanomaterials	Weighing
			Blending and mixing
			Filling
	ES 4	Quality control	Weighing
			Bagging and mixing
	ES 5	Cleaning	Cleaning and maintenance
GES ZnO 3	ES6	Preparation of nanofillers for compounding	Weighing operations
			Blending and mixing
	ES7	Melt compouding at laboratory scale	Feeding phase
			Extrusion
			Cutting
			Cleaning and maintenance of the extruder

Table A16. List of GES identified for nano ZnO in paints

GES CODE	IDENTIFIED USE (IU) NAME	SHORT ES TITLE	SHORT DESCRIPTION OF PROCESS OR ACTIVITY
GES ZnO 1	ES 1	Manufacturing of ZnO nanoparticles by Frame Spray pyrolysis	Synthesis by chemical synthesis
			Handling
			Cleaning and maintenance
	ES 2	Weighing, bagging and packaging of ZnO nanoparticles	Weighing, bagging and packaging of Nanoparticles
GES ZnO 2	ES 3	Manufacturing of intermediates	Weighing
			Blending and mixing
			Cleaning and maintenance
GES ZnO 3	ES4	Formulation mixing with paints	Blending and mixing

Table A17. List of GES identified for $BaSO_4$ in polymers

GES Ba 1 (synthesis)	ES 1	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (dispersion form)	CES 1.1. Sampling during synthesis
			CES 1.2. Discharge from reactor/tank
			CES 1.3. Transfer to small containers (including weighing) and packing
			CES 1.4. Storage
			CES 1.5. Cleaning and maintenance
	ES 2	Nano Ba synthesis. Production of Ba NPs using the wet-chemical process (powder form)	CES 2.1. Sampling during synthesis and physical separation
			CES 2.2. Drying and grinding processess
			CES 2.3. Transfer to containers (including weighing) and packing
			CES 2.4. Storage
			CES 2.5. Cleaning and maintenance
GES Ba 2 Formulation	EES3 S 3	Formulation of Ba containing plastic starting from liquid dispersion	CES 3.1. Loading (including weighing and transferring to reactor/tank)
			CES 3.2. Sampling during formulation
			CES 3.3. Discharge from reactor/tank
			CES 3.3. Storage
			CES 3.4. Cleaning and maintenance
	ES 4	Formulation of Ba containing plastic starting from powders	CES 4.1. Loading (including weighing and transferring to reactor/tank)
			CES 4.2. Sampling during formulation
			CES 4.3. Discharge from reactor
			CES 4.4. Storage
			CES 4.5. Cleaning and maintenance
GES Ba 3 Manufacturing	ES 5	Manufacturing of plastics containing BaSO4 NP	CES 5.1. Storage of raw materials
			CES 5.2. Loading (including weighing and transferring to reactor/tank)
			CES 5.3. Mixing and temperature treatment.
			CES 5.4. Conditioning
			CES 5.5. Cleaning and maintenance
			CES 5.6. Storage and distribution
GES Ba 4 (use)	ES 6	Professional Use of plastics containing BaSO4 nanoparticles	CES 6.1. Usage (abrasion, weathering…)
	ES 7	Consumer Use of plastics containing BaSO4 nanoparticles	CES 7.1. Usage (abrasion, weathering…)

ANNEX III. EXPOSURE SCORES ASSIGNMENT TO DIFFERENT PROCS

Table A1. Occupational inhalation exposure scores associated to different PROCs. These values are based on the worker inhalation exposure predictions provided by ECETOC TRAv3 (details are given in Technical Report 114). As mentioned in the D3.1, the program proposed different values for solids than for liquids. In all cases, the most conservative values for industrial exposure prediction were used since the physical form determinant included in the exposure evaluation (Table 17 of D 3.1) already takes into consideration possible differences between solids and liquids.

	Short description	**Score**
PROC1	Used in closed processes, no likelihood of exposure.	0.01
PROC2	Used in closed , continuous process with occasional controlled exposure	25
PROC3	Use in closed batch process(synthesis or formulation)	50
PROC4	Use in batch or other process (synthesis) where opportunity for exposure arises.	100
PROC5	Mixing or blending in batch processes for formulation of preparations and articles (multistage and/or significant contact)	250
PROC6	Calendering operations	250
PROC7	Industrial spraying	500
PROC8a	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at non-dedicated facilities.	250
PROC8b	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at dedicated facilities.	150
PROC9	Transfer of substance or preparation into small containers (dedicated filling line, including weighing)	200
PROC10	Roller application or brushing	250
PROC11	Non industrial spraying	1000
PROC12	Use of blowing agents in manufactureof foam	100
PROC13	Treatment of articles by dipping and pouring	250
PROC14	Production of preparations* or articles by tabletting, compression, extrusion, pelletisation	250
PROC15	Use as laboratory reagent	50
PROC16	Using material as fuel sources, limited exposure to unburned product to be expected	25
PROC17	Lubrication at high energy conditions and in partly open process	100
PROC18	Greasing at high energy conditions	100
PROC19	Hand-mixing with intimate contact and only PPE available	250
PROC20	Heat and pressure transfer fluids in dispersive, professional use but closed systems	50
PROC21	Low energy manipulation of substances bound in materials and/or articles	10
PROC22	Potentially closed processing opera-tions with minerals/metals at elevated temperature. Industrial setting	10
PROC23	Open processing and transfer opera-tions with minerals/metals at elevated temperature	10
PROC24	High (mechanical) energy work-up of substances bound in materials and/or articles	10
PROC25	Other hot work operations with metals	5

Table A2. Occupational dermal exposure scores associated to different PROCs. These values are based on the worker dermal exposure predictions provided by ECETOC TRAv3 (details are given in Technical Report 114). Similar to that described above, most conservative values were taken since local exhaust ventilation (LEV) mitigation factor was not applied to reduce the initial dermal exposure. To estimate dermal exposure, each PROC takes into account a specific skin exposed area. na indicates non-applicable.

	Short description	**Score**
PROC1	Used in closed processes, no likelihood of exposure.	0,03
PROC2	Used in closed , continuous process with occasional controlled exposure	1,37
PROC3	Use in closed batch process(synthesis or formulation)	0,69
PROC4	Use in batch or other process (synthesis) where opportunity for exposure arises.	6,86
PROC5	Mixing or blending in batch processes for formulation of preparations and articles (multistage and/or significant contact)	13,71
PROC6	Calendering operations	27,43
PROC7	Industrial spraying	42,86
PROC8a	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at non-dedicated facilities.	13,71
PROC8b	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at dedicated facilities.	13,71
PROC9	Transfer of substance or preparation into small containers (dedicated filling line, including weighing)	6,86
PROC10	Roller application or brushing	27,43
PROC11	Non industrial spraying	na
PROC12	Use of blowing agents in manufactureof foam	0,34
PROC13	Treatment of articles by dipping and pouring	13,71
PROC14	Production of preparations* or articles by tabletting, compression, extrusion, pelletisation	3,43
PROC15	Use as laboratory reagent	0,34
PROC16	Using material as fuel sources, limited exposure to unburned product to be expected	0,34
PROC17	Lubrication at high energy conditions and in partly open process	27,43
PROC18	Greasing at high energy conditions	13,71
PROC19	Hand-mixing with intimate contact and only PPE available	141,43
PROC20	Heat and pressure transfer fluids in dispersive, professional use but closed systems	na
PROC21	Low energy manipulation of substances bound in materials and/or articles	2,83
PROC22	Potentially closed processing opera-tions with minerals/metals at elevated temperature. Industrial setting	2,83
PROC23	Open processing and transfer opera-tions with minerals/metals at elevated temperature	1,41
PROC24	High (mechanical) energy work-up of substances bound in materials and/or articles	2,83
PROC25	Other hot work operations with metals	0,28

Table A3. Environmental Release Categories (ERCs) associated to each Process Categories (PROCs), according to the ECHA *Guidance on information requirements and chemical safety assessment (Part D).* PROCs that are not included in the table are not yet applicable. The selection of ERCs needs basic information on the operational conditions of use, therefore these assignments are just orientative. It must be underlined that ERC from 1 to 7 describe the uses in the synthesis and manufacturing stages, ERC 8-11 cover the wide disperse use of a substance by consumers or by many users in the public domain, including small, non industrial companies, and ERC 12 covers the industrial processing of articles with abrasive techniques.

	Short description	**ERC**
PROC1	Used in closed processes, no likelihood of exposure.	1, 6a, 6c
PROC2	Used in closed , continuous process with occasional controlled exposure	1, 6a, 6c, 7
PROC3	Use in closed batch process(synthesis or formulation)	1,2, 6a, 6d
PROC4	Use in batch or other process (synthesis) where opportunity for exposure arises.	1, 6a, 6c, 6d
PROC5	Mixing or blending in batch processes for formulation of preparations and articles (multistage and/or significant contact)	2,3
PROC6	Calendering operations	5
PROC7	Industrial spraying	4,5
PROC8a	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at non-dedicated facilities.	Covered in the industrial ERC
PROC8b	Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at dedicated facilities.	Covered in the industrial ERC
PROC9	Transfer of substance or preparation into small containers (dedicated filling line, including weighing)	Covered in the industrial ERC
PROC10	Roller application or brushing	4, 5, 8a, 8c, 8d, 8f
PROC11	Non industrial spraying	8a, 8c, 8d, 8f
PROC12	Use of blowing agents in manufactureof foam	5
PROC13	Treatment of articles by dipping and pouring	4, 5, 6b, 8a, 8b, 8c, 8d, 8f
PROC14	Production of preparations* or articles by tabletting, compression, extrusion, pelletisation	1,2,3
PROC15	Use as laboratory reagent	8a, 8b
PROC16	Using material as fuel sources, limited exposure to unburned product to be expected	na
PROC17	Lubrication at high energy conditions and in partly open process	4, 8d
PROC18	Greasing at high energy conditions	4, 8d
PROC19	Hand-mixing with intimate contact and only PPE available	8a to 8f

Table A4. Default parameters to derive the environmental release rates from ERC descriptors, according to the ECHA Guideline R.16 (environmental exposure). na indicates non-applicable.

		Default worst case release factors resulting from the conditions of use described in the ERCs		
Number	**ERC**	**To air**	**To water (before sewage treament plant)**	**To soil**
1	Manufacture of chemicals	5%	6%	0.01%
2	Formulation of mixtures	2.5%	2%	0.01%
3	Formulation in materials	30%	0.2%	0. 1%
4	Industrial use of processing aids	100%	100%	5%
5	Industrial inclusion into or onto a matrix	50%	50%	1%
6a	Industrial use of intermediates	5%	2%	0.1%
6b	Industrial use of reactive processing aids	0.1%	5%	0.025%
6c	Industrial use of monomers for polymerisation	5%	5%	0%
6d	Industrial use of auxiliaries for polymerisation	35%	0.005%	0.025%
7	Industrial use of substances in closed systems	5%	5%	5%
8a	Wide dispersive indoor use of processing aids, open	100%	100%	na
8b	Wide dispersive indoor use of reactive substances, open	0.1%	2%	na
8c	Wide dispersive indoor use, inclusion into or onto a matrix	15%	1%	na
8d	Wide dispersive outdoor use of processing aids, open	100%	100%	20%
8e	Wide dispersive outdoor use of reactive substances, open	0.1%	2%	1%
8f	Wide dispersive outdoor use, inclusion in matrix	15%	1%	0.5%
9a	Wide dispersive indoor use in closed systems	5%	5%	na
9b	Wide dispersive outdoor use in closed systems	5%	5%	5%
10a	Wide dispersive outdoor use of long-life articles, low release	0.05%	3.2%	3.2%
10b	Wide dispersive outdoor use of long-life articles, high or intended release	100%	100%	100%
11a	Wide dispersive indoor use of long-life articles, lowrelease	0.05%	0.05%	na
11b	Wide dispersive indoor use of long-life articles, high or intended release	100%	100%	na
12a	Industrial processing of articles with abrasive techniques (low release)	2.5%	2.5%	2.5%
12b	Industrial processing of articles with abrasive techniques (high release)	20%	20%	20%

ANNEX IV. MAPPING OF USES FOR THE PRIORITIZATION OF EXPOSURE SCENARIOS

The links below open the excel files that contain the detailed exposure scenarios with the algorithms to obtain the exposure ranking scores.

Figure A10. Mapping of uses for Ag in textiles

Mapping of
Uses_potential expos

Figure A11. Mapping of uses for TiO_2 in textiles

Mapping of
Uses_potential expos

Figure A12. Mapping of uses for CNT in composites and polymer products

CNTs_LS+SS_12091
4_leitat.xls

Figure A13. Mapping of uses for TiO_2 nanoparticles in paints

Mapping of
Uses_TiO2__potentia

Figure A14. Mapping of uses for SiO_2 in packaging

Mapping of
Uses_SiO2_packaginç

Figure A15. Mapping of uses for Ag in packaging

Mapping of
Uses_AgPACKAGING_

Figure A16. Mapping of uses for ZnO in paints

Mapping of
Uses_ZnO_paints_po

Figure A17. Mapping of uses for ZnO in cosmetics

Mapping of
Uses_ZnOCOSMETIC

Figure A18. Mapping of uses for ZnO in packaging

Mapping of
Uses_ZnPackaging_0

Figure A19. Mapping of uses for Ag in construction

Mapping of
Uses_Ag_AIDICO_v2

Figure A20. Mapping of uses for TiO_2 in construction

Mapping of
Uses_TiO2_AIDICO_

Figure A21. Mapping of uses for ZnO in construction

Mapping of
Uses_ZnO_AIDICO_

Figure A22. Mapping of uses for Ag in electronics

Mapping of
Uses_Ag_Electronic_

Figure A23. Mapping of uses for CNT in energy applications

Mapping of
Uses_CNT_Energy_L

Figure A24. Mapping of uses for nanocellulose in paper and composites

Mapping of Uses
cellulose potential ex

Figure A25. Mapping of uses for CeO_2 in catalyst

Mapping of Uses
ceo2 catalyst potenti

Figure A26. Mapping of uses for CeO_2 in electronics

Mapping of Uses
ceo2 electronic poten

Figure A27. Mapping of uses for CeO_2 in paints

Mapping of Uses
ceo2 paint potential e

Figure A28. Mapping of uses for TiO_2 in cosmetics

Mapping of Uses
formulation Tio2 cosm

Figure A29. Mapping of uses for SIO_2 in concrete

Mapping of Uses Sio2
concrete potential ex

Figure A30. Mapping of uses for SiO_2 in electronics

Mapping of Uses Sio2
electronics potential e

Figure A31. Mapping of uses for $BaSO_4$in drilling applications

Mapping of Uses
BaSO4 drilling02.xls

Figure A32. Mapping of uses for $BaSO_4$in plastics, paints and varnishes

Mapping of Uses
BaSO4-CL_JR.xls

Figure A33. Updated Mapping of uses for all ENM (inhalation and dermal occupational exposure scores)

scores occupational
inhalation&dermal_ ex

Figure A34. Updated Mapping of uses for all ENM (environmental exposure scores)

scores
environmental_24nov

ANNEX V. ADDITIONAL FIELDS TO BE INCORPORATED IN OCCUPATIONAL EXPOSURE SCENARIOS TO ENABLE PREDICTION OF ENVIRONMENTAL RELEASE

<table>
<tr><td colspan="4">Operational conditions affecting environmental exposures</td></tr>
<tr><td colspan="2"></td><td>Duration</td><td></td></tr>
<tr><td colspan="4">Technical onsite conditions and measures to reduce or limit discharges, air emisions and release to soil</td></tr>
<tr><td>Technical measures (prevention)</td><td></td><td>Technical measures (dispersion)</td><td></td></tr>
<tr><td colspan="4">Organizational measures to prevent/limit release from site</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Conditions and measures related to municipal sewage treatment plan</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Waste Management Measures</td></tr>
<tr><td>Information on measures to control risk during production and use stages of substance, preparation or article</td><td colspan="3"></td></tr>
<tr><td colspan="4">Other control measures</td></tr>
<tr><td colspan="4"></td></tr>
</table>