Scaffold Public Documents - **SPD1**

Innovative strategies, methods and tools for occupational risks management of manufactured nanomaterials (MNMs) in the construction industry

LIFE CYCLE ANALYSIS OF NANO-TiO2, NANO-SiO2, CARBON NANOFIBRES, CELLULOSE NANOFIBRES AND NANOCLAYS IN THE CONSTRUCTION SECTOR

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1. EXECUTIVE SUMMARY

This document aims in the development of Life Cycle Analysis (LCA) of different processes involved in the construction sector. This LCA will allow identifying the potential Exposure flows and Scenarios (ES) in each process and the Nanomaterials (NMs) flow involved in these ES.

For this purpose, a methodology is followed that consist on the identification of different tasks involved in each process (the identified tasks are related to the Life Cycle (LC) steps defined in the document, so that, tasks out of these steps are not considered such as design or use of the product). After that, the NM related to each task is identified and it is evaluated if operations regarding to the tasks are considered as potential exposure scenarios to the worker.

As a result, different diagrams are presented for each process, in which the NMs flow is highlighted as well as the description of the process and the potential ES.

The main conclusion is that many processes are related to same ES, so it is possible to analyze ES which are usable for different processes. In fact, the analysis of less ES is required reducing for instance the quantity of measurements to be carried out. As a result, 26 ES are going to be analyzed although possible ES are 126.

ES are classified also in different presentations of the NMs such as dust, embedded in liquid, and dust mixed with other particles (other nature). As a first approach, NM presentation is classified: pure dust (dust of NM), mixed dust (NM mixed with other compounds, for instance cement or grave), liquid embedded with NM.

2. OBJECTIVES

This document aims in the development of Life Cycle Analysis (LCA) of different processes involved in the construction sector. The specific objectives are:

- To carry out the LCA of all the processes involved in the construction sector previously identified in the Description of Work (DoW).

- The analysis of the MNMs flow in all the processes involved in the construction sector in order to identify worker exposure to the 5 NMs (**TiO_2, SiO_2, Nanoclays**, Cellulose Nanofibres **(CellNF)**, Carbon Nanofibres **(CNF)**) selected in the scope of the project.

- The identification of ES previously defined in the DoW for each process.

For this purpose, the report has been divided in 4 parts:

- Scope: This part of the document describes the scope defined in the DoW.

- Introduction: It refers to the description of the construction sector, the 5 NMs, the 6 applications of MNMs and the 6 ES involved in the project.

- Methodology: Here the methodology to the LCA is described step by step. First the LC of the process is described, then the tasks involved in the different processes are identified and classified in the LC and it ends up with the MNMs flow definition for each process.

- Results: The results obtained by the methodology are presented.

- Conclusions: Based on the results main conclusions are highlighted.

3. SCOPE

As it is pointed out in the *2.Objectives* part, it will be developed the LCA for the processes involved in the construction sector, but first it is necessary to remark the scope of the project:

- Selected ES are related to steps 2, 3 and 4 of the LC, which are Operation or construction, Maintenance and Demolition or dismantle respectively and the USE step is analyzing in the NANOHOUSE [1] project.

It is necessary also to highlight some notes:

- NOTE 1:

  According to the experience of ACCIONA, the application related to Bituminous road development will be analyzed with the use of CNF and Nanoclays.

- NOTE 2:

  Operations like machining or assembly are involved both in the *Step 2 Operation or construction* of the LC and in the *Step 3.Maintenance and use*. In the document they are only considered in the step 2 in order not to repeat ES related to these operations.

4. INTRODUCTION

4.1. Short description of the construction sector

According to the functions given to a construction element, traditionally the construction field has been divided in **Building** Construction and **Civil** Construction. This classification implies that the first type of construction is designed to host people and the second is designed to ease people´s activities. The classification of the construction sector is shown in the diagram below.

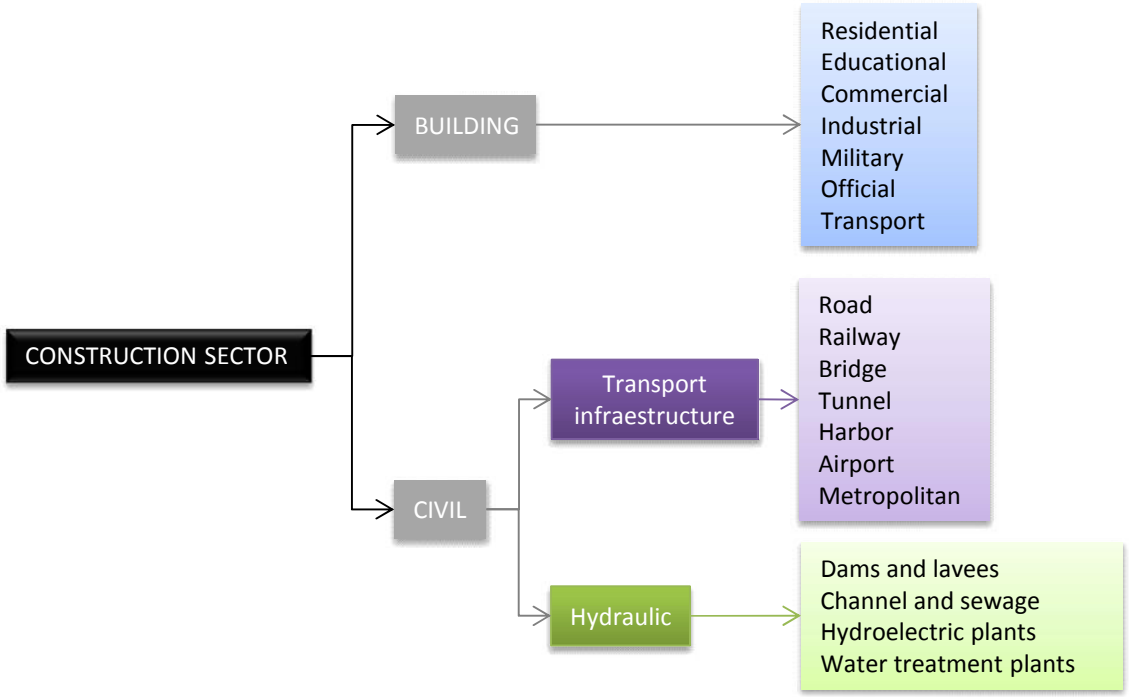


Figure 1 *Diagram of the construction process*

Building Construction

Traditionally the buildings are classified according to their use; therefore there is a very large number of building types. The scheme collects the most relevant ones: residential, educational, commercial, industrial, military, official, and those destined to sport activities.

The construction of a building is a very long process that involves activities such as design or planning, promoting, sub-contractions, machinery, clearance, demolition, etc.

Civil Construction

The civil constructions can be sub-classified in many ways; in this case they have taken into account whether they are transport infrastructures, or hydraulic constructions.

Within the **transport infrastructures**, one can find at least the following types:

- **Roads**. A road is a thoroughfare, route, or way on land between two places, which typically has been paved or otherwise improved to allow travel by some conveyance, including a horse, cart, or motor vehicle. Roads consist of one, or sometimes two, roadways each with one or more lanes and also any associated sidewalks and road verges. Roads that are available for use by the public may be referred to as public roads or highways.

- **Railways**. Rail transport is a means of conveyance of passengers and goods by way of wheeled vehicles running on rail tracks. In contrast to road transport, where vehicles merely run on a prepared surface, rail vehicles are also directionally guided by the tracks on which they run. Track usually consists of steel rails installed on sleepers/ties and ballast, on which the rolling stock, usually fitted with metal wheels, moves. However, other variations are also possible, such as slab track where the rails are fastened to a concrete foundation resting on a prepared subsurface.
- **Bridges**. A bridge is a structure built to span physical obstacles such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed, the material used to make it and the funds available to build it.
- **Tunnels**. A tunnel is an underground passageway, completely enclosed except for openings for ingress and egress, commonly at each end. A tunnel may be for foot or vehicular road traffic, for rail traffic, or for a canal. Some tunnels are aqueducts to supply water for consumption or for hydroelectric stations or are sewers. Other uses include routing power or telecommunication cables, some are to permit wildlife such as European badgers to cross highways.
- **Harbors**. A harbor is a place where ships, boats, and barges can seek shelter through stormy weather, or else are stored for future use. Harbors can be natural or artificial. An artificial harbor has deliberately-constructed breakwaters, sea walls, or jetties, or otherwise, they could have been constructed by dredging, and these require maintenance by further periodic dredging.
- **Airports**. An airport is a location where aircraft such as fixed-wing aircraft, helicopters, and blimps take off and land. Aircraft may be stored or maintained at an airport. An airport consists of at least one surface such as a runway for a plane to take off and land, a helipad, or water for takeoffs and landings, and often includes buildings such as control towers, hangars and terminal buildings.
  In terms of the steps, they could be summarized as the combination of those to build a **road** plus those to build a **building**.
- **Metropolitans**. A metropolitan railway system is an electric passenger railway in an urban area with a high capacity and frequency, and grade separation from other traffic. Rapid transit systems are typically located either in underground tunnels or on elevated rails above street level. Outside urban centers, rapid transit lines may run on grade separated ground level tracks.
  In terms of the steps, they could be summarized as the combination of those to build a **tunnel** plus those to build a **railway**.

Within the **hydraulic constructions**, one can find at least the following types:

- **Dams and levees**. A dam is a barrier that impounds water or underground streams. Dams generally serve the primary purpose of retaining water, while other structures such as floodgates or levees (also known as dikes) are used to manage or prevent water flow into specific land regions. A levee is an elongated naturally occurring ridge or artificially constructed fill or wall, which regulates water levels. It is usually earthen and often parallel to the course of a river in its floodplain or along low-lying coastlines.
  The construction steps to build these elements are similar to those for a harbor.
- **Channels and sewages**. A channel or water supply canals are used for the conveyance and delivery of potable water for human consumption, municipal uses, and agriculture irrigation. Sewage is water-carried waste, in solution or suspension that is intended to be removed from a community.

The construction steps to build these elements are similar to those for a tunnel.

- **Hydroelectric plants.** It is a plant where hydroelectricity is produced. Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. The construction steps to build these elements are similar to those for an industrial building.
- **Water treatment plants.** Water treatment describes those processes used to make water more acceptable for a desired end-use. These can include use as drinking water, industrial processes, medical and many other uses. The goal of all water treatment process is to remove existing contaminants in the water, or reduce the concentration of such contaminants so the water becomes fit for its desired end-use. One such use is returning water that has been used back into the natural environment without adverse ecological impact.

  The construction steps to build these elements are similar to those for an industrial building plus a further exploitation. Note that in some water treatment plants, nanotechnology has started to be used.

According to the descriptions presented above, there are some similarities between different processes which can be analyzed as if they were the same process or as a combination of two processes. Next diagram summarizes the combinations between all the infrastructures to be studied in the project:

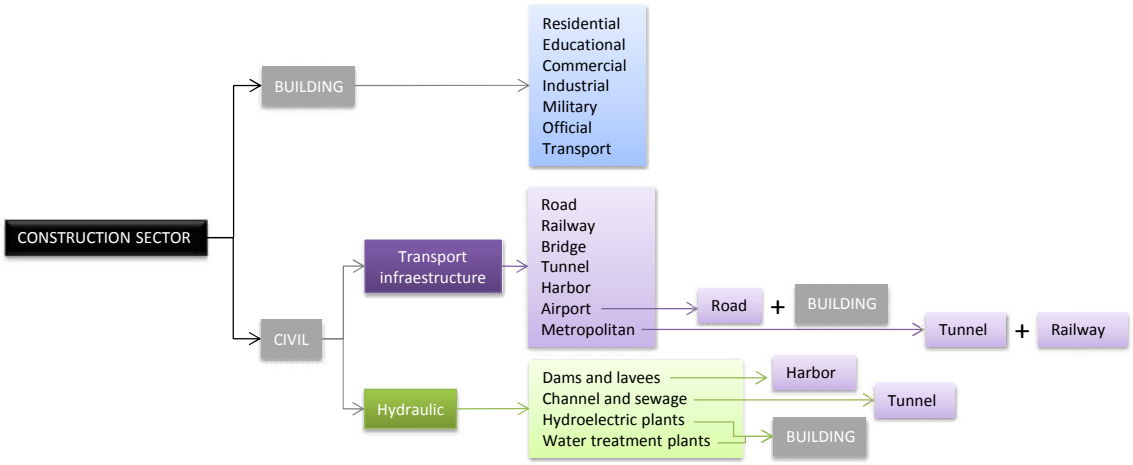


Figure 2. *Combination of different processes to be analyzed in the process*

4.2. Description of the 5 NMs studied in the project

The descriptions below are from FIOH's report 'Background information on exposure, use, and hazard of manufactured nanomaterials in the construction sector' (Karjalainen *et al.*, 2012).

TiO_2

Titanium dioxide is the naturally occurring oxide of titanium. Often distinction is made by TiO_2 manufacturers between pigmentary and ultrafine grade. The primary crystal size typically ranges from 150 to 300 nm for TiO_2 of pigmentary grade and the surface area from 6 to 60 m2/g. The ultrafine grade typically has a primary crystal size from 10 to 150 nm, and surface area between 50 and 200 m2/g. The pigmentary TiO_2 has a white colour and is therefore widely used in paints etc. The ultrafine, including nano-sized, TiO_2 is transparent. In contrast to the bulk TiO_2 (>100 nm) that is considered chemically inert, nano-scale TiO_2 can act as a photo-catalyst, and can generate reactive oxygen species upon illumination. A wide range of

applications exist, exploiting the various properties of TiO_2 nanomaterials. In paints and for water treatment nano-sized TiO_2 is used as a photocatalysist producing reactive oxygen that may degrade other organics. Adding nano-TiO_2 into concrete aims to enhance its' durability and to maintain whiteness throughout the lifetime of the construct. In glass nano-TiO_2 is used for heat and fire protection and for its' self-clean properties. A number of other very diverse areas of application exist such as catalysts, toothpaste, sunscreens and other cosmetics, air filtration devices, semiconductors, etc. (van Broekhuizen et al. 2011)

SiO_2 (amorphous silica)

There are several different forms of silica. A common CAS number for all silicas is 7631-86- 9. However, each different polymorph of silica has its own polymorph specific CAS number.

Amorphous silica can be divided to synthetic amorphous silicas, natural amorphous silicas (like diatomaceous earth) and by-products metal industry (silica fume). Natural forms of amorphous silica may contain impurities, particularly crystalline silica (OECD 2004; ECETOC 2006; Napierska et al. 2010). The physico-chemical properties and particle characteristics differ between different amorphous silica polymorps.

Nanoclays

Nanoclays are nanoparticles formed of layered mineral silicated and they are commonly blended with polymers to form nanocomposites. Nanoclays and polymer-layered nanocomposites are used in a wide range of applications, e.g. in the production of inks, paints, cosmetics, in water treatment applications, and food packaging products. As with other nanosized materials also nanoclays may have toxic effects which are not apparent in the bulk material (Lordan et al. 2011).

CellNF

Cellulose fibres are extensively used in paper production, cotton textiles, and as insulation and structural strengtheners in construction products. Despite the large scale use of cellulose fibres their possible toxic properties have not been as rigorously tested as for asbestos and other man-made fibres. Inhalation or instillation studies with cellulose fibres in rats and hamsters have shown that the fibres can cause different pathological changes. It has also been shown that intraperitoneal injections (3 injections spaced at weekly intervals) of high doses of cellulose fibres can cause tumours (sarcomas) in the abdominal cavity of male Wistar rats (Cullen et al. 2002b).

CNF

Carbon nanofibres (CNFs) typically have a diameter of 50-200 nm and structurally they resemble MWCNTs. The primary characteristic that makes them different from CNTs is the grapheme alignment - if the graphene plane and fiber axis do not align, the structure is defined as a CNF. It is less expensive to produce CNFs as compared to CNTs and they are used, for example, in composite materials to improve strength, stiffness, electrical conductivity, or heat resistance (Kisin et al. 2011). Despite the widespread use of CNFs, their toxicity has not been extensively studied.

4.3. Description of the 6 applications of MNMs studied in the project

Depollutant mortar

The addition of **TiO_2** to the common mortar implies the improvement of barrier properties of the material. These MNMs add to the mortar the capacity to maintain the surface of the

product clean more time than the common mortar, therefore the maintenance tasks of the product will be reduced during the use of the product.

Self-compacting concrete

SiO_2 particles help to the concrete to improve the surface properties of the material. Mainly in irregular formwork, some superficial cracks and porosities are produced which are caused by the contraction of the material and the quality of the surface is considerably reduced whereas the addition of this MNM avoids the apparition of these discontinuities.

Road surface

The asphalt doped by **Nanoclays** or **CNF** has better barrier properties against the inclemency of the weather (high temperatures, rain…) or the transit of heavy motor vehicles, reducing for instance, the maintenance operations during their use.

Self-cleaning mortar

Self-cleaning mortar has the same properties as the depollutant mortar but in this case this material is going to be applied on the road as a coating instead of being applied in a wall.

FR panels

FR panels are prefabricated structural elements for use in building walls, ceilings, floors, and roofs. They provide superior and uniform insulation compared to more traditional construction methods. Different nano-powders are used as mass-ingredients in the technology of Structural Insulated Panels at different dosages up to 20% by weight in order to enhance Fire Retardant properties. The main **nanoclay** reinforcements used are of hydrated sodium calcium aluminium silicate.[2]

Insulation panels

Insulation panels are prefabricated structural elements for use in building walls, ceilings, floors, and roofs. One of the nanomaterials that can improve insulation properties in the prefabricated panels is **CellNF**.

In the table below is summarized the MNMs used in each application to be produced in the project:

MNM	APPLICATION	
TiO_2	Depollutant mortar	Wall covered by the depollutant mortar
	Self-cleaning mortar	Paving stones covered by the self-cleaning mortar
SiO_2	Self-compacting concrete	Structural piles or columns made of this kind of concrete
CNF / Nanoclay	Bituminous Road surface	Asphalt doped with nanoclays / CNF
Nanoclay	FR panels	Prefabricated FR panels reinforced with Nanoclays
CellNF	Insulation panels	Prefabricated insulation panels reinforced with CellNF

Table 1 *Relation between MNMs and the application*

4.4. Description of the 6 categories of ESs studied in the project

According to the DoW, 6 categories of ES will be analyzed during the LCA of all the processes involved in the project.

- ES1: Manufacturing NMs

  It refers to the tasks related to the manufacturing of **TiO_2** and **SiO_2** carried out in the facilities of TECNAN.

- ES2: Formulations containing MNMs

  The mixing process of the NM (**TiO_2, SiO_2, Nanoclay, CellNF, CNF**) with other components such as cement, sepiollite, water...

- ES3: Application of the material

  It refers to the application task of the MNMs. i.e. mortar application with a trowel, shotcrete, spraying…

- ES4: Assembly and machining

  It is related to the maintenance operations carried out in the product during its use. i.e. sawing, machining, drilling…

- ES5: Demolition and disposal

  It is regarding end of life operations like compacting to recycling, grinding, demolition…

- ES6: Accidental fires

  It regards to the emission of nanoparticles generated during a fire caused by an accident.

4.5. Relation between Processes, NMs, Applications or MNMs and categories of ES

The table below relates the four variables involved in the LCA that are described above: All the processes of the construction sector, the 5 NMs used in each process, the 6 applications of these MNMs in each process and the 6 categories of ES involved in each process.

The first process is the Manufacturing of NMs, which only includes the manufacturing of **SiO_2** and **TiO_2** and it is related to the ES1 because it is only a development of the raw material. In the rest of the processes the scenarios studied will go from ES2 to ES6.

In the Building process 4 MNMs (**TiO_2, SiO_2, Nanoclay, CellNF**) will be used as well as in the Hydroelectric Plants and Water Treatment Plant construction processes.

In Railway, Bridge, Harbour and Dams and Lavees construction processes only MNMs containing **SiO_2** will be used.

Nanoclay and **CNF**[1] will be used in the construction of Tunnel and Channels & Sewage whereas in the Metropolitan construction will use also **SiO_2** apart from the **Nanoclay** and **CNF**[1].

In the airpor construction sector process all the MNMs (**TiO_2, SiO_2, Nanoclay, CellNF, CNF**) are going to be used.

Finally, Road will be constructed using products containing **TiO_2** and **Nanoclay** and **CNF**[1].

[1] The use of Nanoclays in these processes is due to the experience of ACCIONA developing Asphalts dopped with these nanomaterials (see point *3. Scope* in this document)

CONSTRUCTION SECTOR PROCESSES			APPLICATION OF MNMs	NM	CATEGORIES OF ES
1 MANUFACTURING NANOMATERIALS				**SiO_2** **TiO_2**	ES1 ES2
2 BUILDING		Residential Educational Commercial Industrial Military Official Transport	Self-compacting concrete Insulation panels FR panels Depollutant mortar	**SiO_2** **CellNF** **Nanoclay** **TiO_2**	ES3 ES4 ES5 ES6
3 CIVIL	3.1 Transport infrastructure	Road	Self-cleaning mortar Road surface	**TiO_2** **Nanoclay/CNF**	
		Railway Bridge	Self-compacting concrete	**SiO_2**	
		Tunnel	Road surface	**Nanoclay/CNF**	
		Harbor	Self-compacting concrete	**SiO_2**	
		Airport	Self-compacting concrete Insulation panels FR panels Depollutant mortar Self-cleaning mortar Road surface	**SiO_2** **CellNF** **Nanoclay** **TiO_2** **TiO_2** **Nanoclay/CNF**	
		Metropolitan	Road surface Self-compacting concrete	**Nanoclay/CNF** **SiO_2**	
	3.2 Hydraulic	Dams and lavees	Self-compacting concrete	**SiO_2**	
		Channels & sewage	Road surface	**Nanoclay/CNF**	
		Hydroelectric plants	Self-compacting concrete Insulation panels FR panels Depollutant mortar	**SiO_2** **CellNF** **Nanoclay** **TiO_2**	
		Water treatment plants			

Table 2 *Relation between Processes, MNMs and Applications*

5. METHODOLOGY

In this part of the report it is explained the methodology followed in order to identify the MNM flow and the ES involved in each process along the LCA of the processes involved in the construction sector.

First of all the steps of the LC are defined and then the processes are divided in different tasks (all the tasks will be operations carried out into the steps of the LC defined in the next point). After this division the NM used in each task will be identified as well as defined its flow.

5.1. Life Cycle Analysis (LCA) of the processes

The life cycle has been divided in four main steps that are: 1) Design, 2) Operation or construction, 3) Maintenance & use and 4) Demolition. (See next figure).

Figure 3 *LC of the process and the ES involved in each step*

1) Design

The first step involved in the life cycle is the design of the product in which is taken into account the previous planning, CAD design, structural calculations…

2) Operation or construction

The operation or construction step involves all the construction process such as clearance, drainage or finishing tasks. The ES related to this step are: ES1, ES2, ES3, ES4.

3) Maintenance & use

This third step is composed by two tasks, maintenance and use. The step that is going to be analyzed in the project is the maintenance of the infrastructure during the use (tasks like machining, sawing or drilling) whereas the use is studied in the NANOHOUSE [1] project. The ES related to this step is ES6 but tasks considered in the ES4 could be involved in this one (see *3. Scope*)

4) Demolition or dismantle

Demolition is the last step into the process life cycle, in which it is considered the end of life of the product i.e. grinding. ES5 is considered as the scenario involved in this step.

After defining the LC steps, all the processes have been divided in tasks which have been integrated into the LC steps.

5.2. MNMs flows in the life cycle of the process

Once the 6ES are classified into the LC, tasks related to each ES are identified in all the processes. After that, tasks considered as potential scenarios and the NM in terms of worker exposure are identified. The result of this classification is the MNM flow definition.

6. RESULTS

Following the methodology described above, the results regarding LCA of all the processes involved in the construction sector are presented as diagrams.

Each diagram is related to each process and a description of the tasks is given as well as the MNM involved.

- NOTE 5:

  It is necessary to highlight that the nomenclature used in the following diagrams regarding 6 applications of ES differs from the nomenclature used up to now in the document. The reason why a new nomenclature is defined is because there in some processes are different NMs to be analyzed in the same category of ES, therefore, is a way to distinguish the same ES involved in different NMs used. The nomenclature of ES, hence, will be:

STEPS IN THE LIFE CYCLE		CATEGORY OF ES (defined in the DoW)	ES (in the diagrams)
1	Design	*Out of the scope*	
2	Operation and construction	ES1 ES2 ES3 ES4	**ES1** *(TiO_2)* **ES2** *(TiO_2)* **ES3** *(TiO_2)* **ES6** *(SiO_2)* **ES7** *(SiO_2)* **ES8** *(SiO_2)* **ES11** *(Nanoclay)*/ **ES11** *(CNF)* **ES12** *(Nanoclay)*/ **ES12** *(CNF)* **ES15** *(TiO_2)* **ES16** *(TiO_2)* **ES19** *(Nanoclay)* **ES20** *(Nanoclay)* **ES23** *(CellNF)* **ES24** *(CellNF)*
3	Maintenance & use[2]	ES6	**ES5** *(TiO_2)* **ES10** *(SiO_2)* **ES14** *(Nanoclay)*/ **ES14** *(CNF)* **ES18** *(TiO_2)* **ES22** *(Nanoclay)* **ES26** *(CellNF)*
4	Demolition or dismantle	ES5	**ES4** *(TiO_2)* **ES9** *(SiO_2)* **ES13** *(Nanoclay)*/ **ES13** *(CNF)* **ES17** *(TiO_2)* **ES21** *(Nanoclay)* **ES25** *(CellNF)*

Table 3 *Relation between Processes, MNMs and Applications*

- NOTE 6:

  In some processes NM called **Other** is considered because in some operations (mainly in demolition) can be generated nanoparticles of unknown nature.

[2] The use of the MNMs is out of the scope of the project as it is explained in the point 3.Scope of this document.

PROCESS: MANUFACTURING NANOMATERIALS

It refers to the description of manufacturing two types of NMs:

1. STEPS INVOLVED IN THIS TASK

1) **Design.** *Out of the scope of the project.*
2) **Operation or construction**

   a. Precursors mixing. All the chemical components are introduced in a closed reactor. No emission of any nanoparticle it is considered in this task.

   b. Reaction in a spark ignition chamber. It is the moment when a reaction occurs and nanoparticles generate. No emission of nanoparticle it is considered because the reaction is performed in a closed chamber.

   c. Deposition of MNMs in filters. After the reaction the generated nanoparticles are deposited automatically in filters. No emission of nanoparticles is considered because the deposition operation is performed automatically.

   d. Packaging. During the packaging process the transfer of the powders is performed manually, so it is could be a potential emission of **SiO_2** and **TiO_2** during this process.

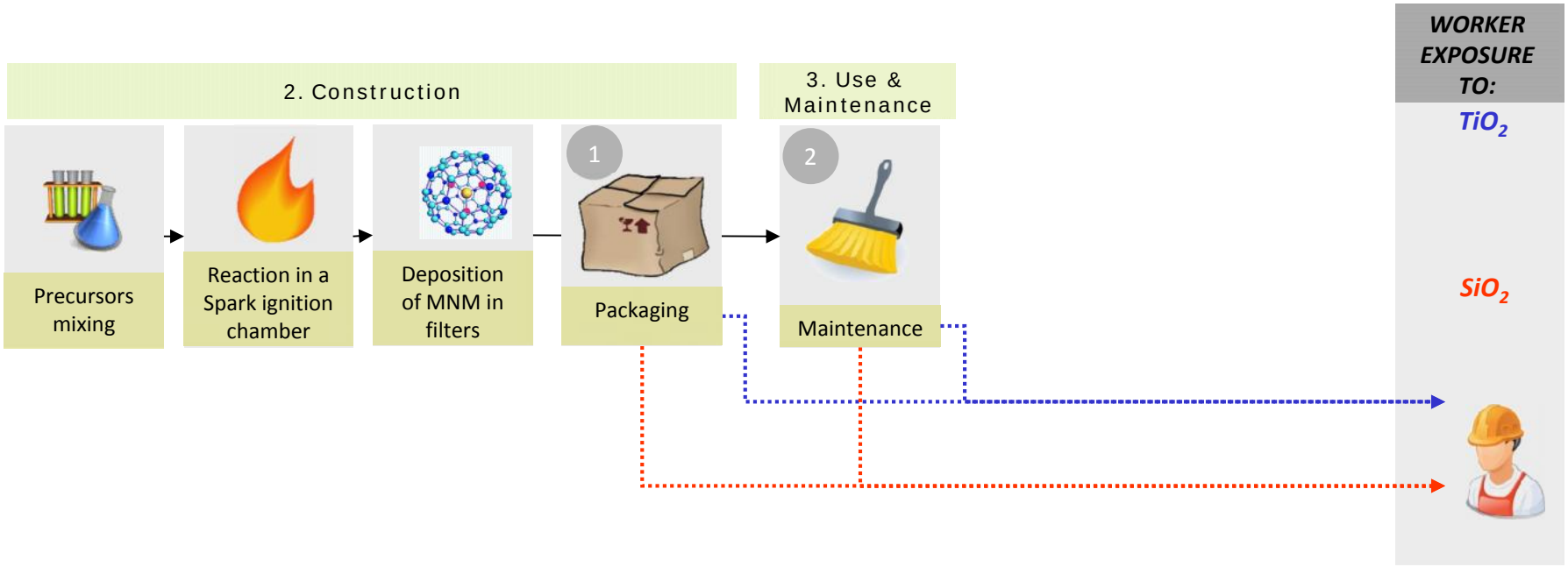
3) **Maintenance.** In this task are considered operations like cleaning the filters after the manufacturing process. Therefore, there will be the release **SiO_2** and **TiO_2**.
4) **Demolition or dismantle.** This task is not considered in this process

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **TiO_2**, **SiO_2**.

3. NANOMATERIAL FLOW

MANUFACTURING NANOMATERIALS



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Packaging	ES1/ ES6: Manufacturing NMs & Formulations containing MNMs	SiO_2 TiO_2
2. **Maintenance**		ES1/ ES6: Manufacturing NMs & Formulations containing MNMs	

PROCESS: BULDING

Into the building process are considered: Residential, Educational, Commercial, Industrial, Military, Official and Transport buildings construction processes in which are involved the same steps that are described below.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Clearance and demolition. It is the preparation of the soil before starting the edification. It is considered the demolition if the previous building and the cleaning and preparation of the soil. In this task would be **other nanomaterial release**[3].

b. Formwork and concrete. It is the construction and the establishment of the molds where the concrete is going to poured in. In this task there is not considered any nanomaterial release.

c. Foundation laying. It is the pouring of the concrete into the molds previously constructed and established. The concrete is doped by **SiO_2** so it is considered this **nanomaterial release**.

d. Insulations and Fire Retardant (FR) panels. This task is related to panel collocation either insulation panel or FR panels. Insulation and RF panels are doped with **CellNF** and **Nanoclay** respectively, so it is consider a release of these nanomaterials during the collocation process.

e. Iron works, walls, plumbing. It is regarding the installation of common facilities (plumbing, electricity…) and construction of walls. In this tasks wall doped with **TiO_2** so it is consider the **release** of these particles.

f. Finishing, paint, polish. Here are the tasks related to finishing operations such as painting or polishing of the surfaces. i.e. wall painting. In this task would be **other nanomaterial release**.

3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2**, **CellNF**, **Nanoclay** and **TiO_2** MNMs.

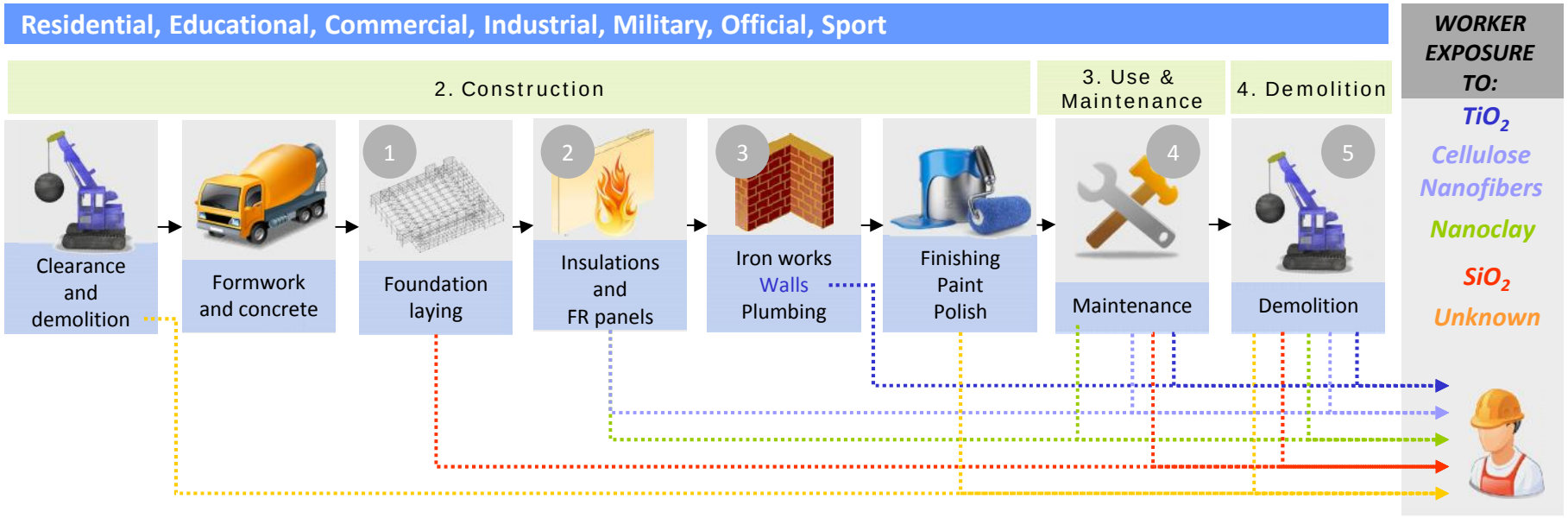
4) **Demolition or dismantle.** Demolition of the whole building, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2**, **CellNF**, **Nanoclay, TiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **TiO_2, SiO_2, CellNF, Nanoclay, Other**.

[3] It is considered the release of nanoparticles no considered in the Project.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Foundation laying	**ES7**:Concrete mixing piles, slabs and special structures	SiO_2
		ES8:On- site assembly/machining	
	2. Insulations and FR panels	ES19/ES23:Off-site manufacturing → *not considered in the project*	NC CellNF
		ES20/ES24:Fitting of the panels and machining for the superficial instalations of other elements	
	3. Walls	**ES2**:Monolayer rendering application	TiO_2
		ES3:On site assembly/machining	
4. **Maintenance**		**ES10**/**ES5**/ES22/ES26:Accidental fire: MNM combustion	SiO_2 TiO_2 NC CellNF
5. **Demolition or dismantle**		**ES9**/**ES4**/ES21/ES25:Demolition, end of life	

PROCESS: CIVIL – Transport Infrastructure - ROAD

In this process there are described the steps involved in ROAD construction. In the operation step there are 2 different possibilities to construct the road: only grouting or a combination between bituminous road and compacting. (see next diagram)

1. STEPS INVOLVED IN THIS TASK

1) **Design.** *Out of the scope of the project.*
2) **Operation or construction**

   a. Clearance and demolition. It is the preparation of the soil before starting the edification. It is considered the demolition if the previous infrastructure and the cleaning of the soil. In this task would be **other nanomaterial release**.

   b. Excavation, filling, compacting. It is the preparation of the soil before starting pouring the road material. In this task there is not considered any nanomaterial release.

   c. 1.Grouting. It is the pouring of the road material. The material is doped by **TiO_2** so it is considered this **nanomaterial release**.

   c. 2.1. Bituminous road. This task is related to the pouring of the road material. The poured material is a bituminous road containing **CNF** and **NC**, so it is consider a release of these nanomaterials.

   c. 2.2. Compacting. This task is to compact the material previously poured so it is not considered any MNM release.

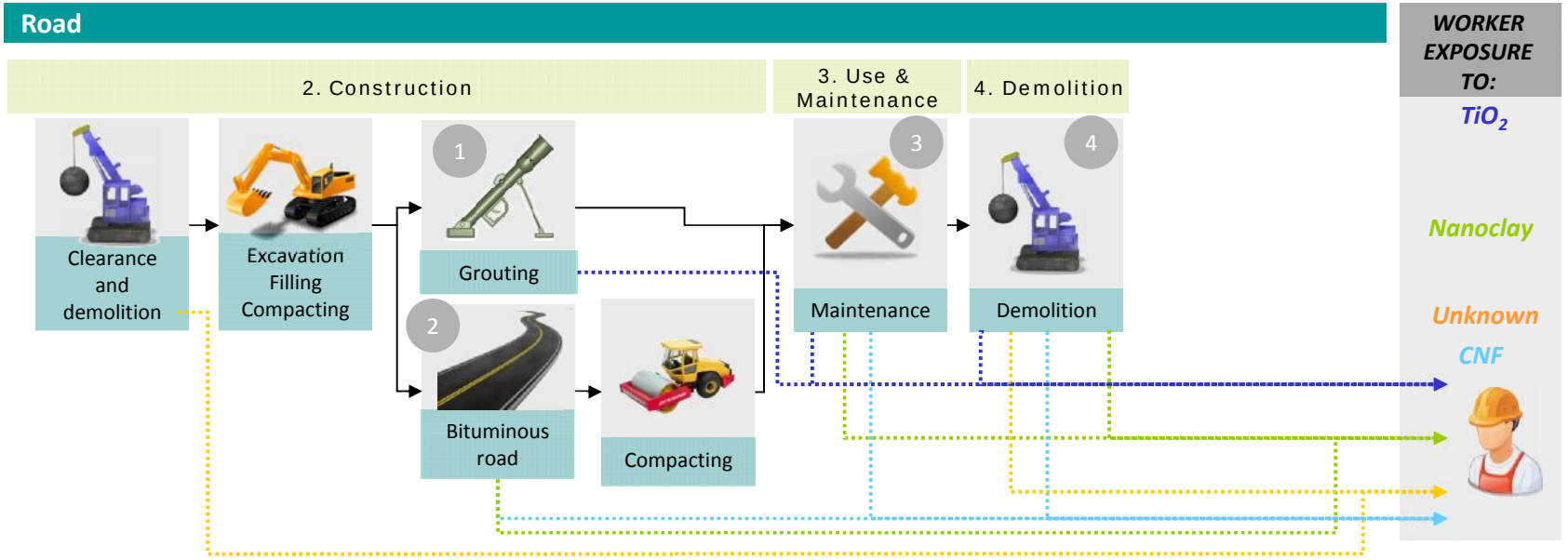
3) **Maintenance.** In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of all the nanoproducts used in this process. Therefore, there will be the release of **CNF**, **NC** and **TiO_2** MNMs.

4) **Demolition or dismantle.** Demolition of the road, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **CNF**, **TiO_2**, **NC** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **TiO_2, CNF, NC, Other**.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Grouting	**ES15**:Preparation, dosification and application	TiO_2
		ES16: Superficial machining	
	2. Bituminous road	**ES11**/ES11:Manufacture in-site of the pavements	NC[4] CNF
		ES12/ES12:Machining for superficial fitting of other elements	
3. **Maintenance**		**ES18**/**ES14**/ES14:Accidental fire: MNM combustion	TiO_2 NC CNF
4. **Demolition or dismantle**		**ES17**/**ES13**/ES13:Demolition, end of life	

[4] The NC is considered in this process due to the experience of ACCIONA in the use of Nanoclays in asphalts.

PROCESS: CIVIL – Transport Infrastructure - RAILWAY

In this process there are described the steps involved in RAILWAY construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Clearance and demolition. It is the preparation of the soil before starting the edification. It is considered the demolition if the previous infrastructure and the cleaning of the soil. In this task would be **other nanomaterial release**.

b. Excavation, filling, compacting. It is the preparation of the soil before starting the pouring of the concrete. In this task there is not considered any nanomaterial release.

c. Concrete. It is the pouring of the concrete. The material is doped by **SiO_2** so it is considered this **nanomaterial release**.

d. Railway installation. During this task will be machining operations that will generate **SiO_2** dust.

d. Electrical installation. Electrical installation will not generate any nanoparticle release.

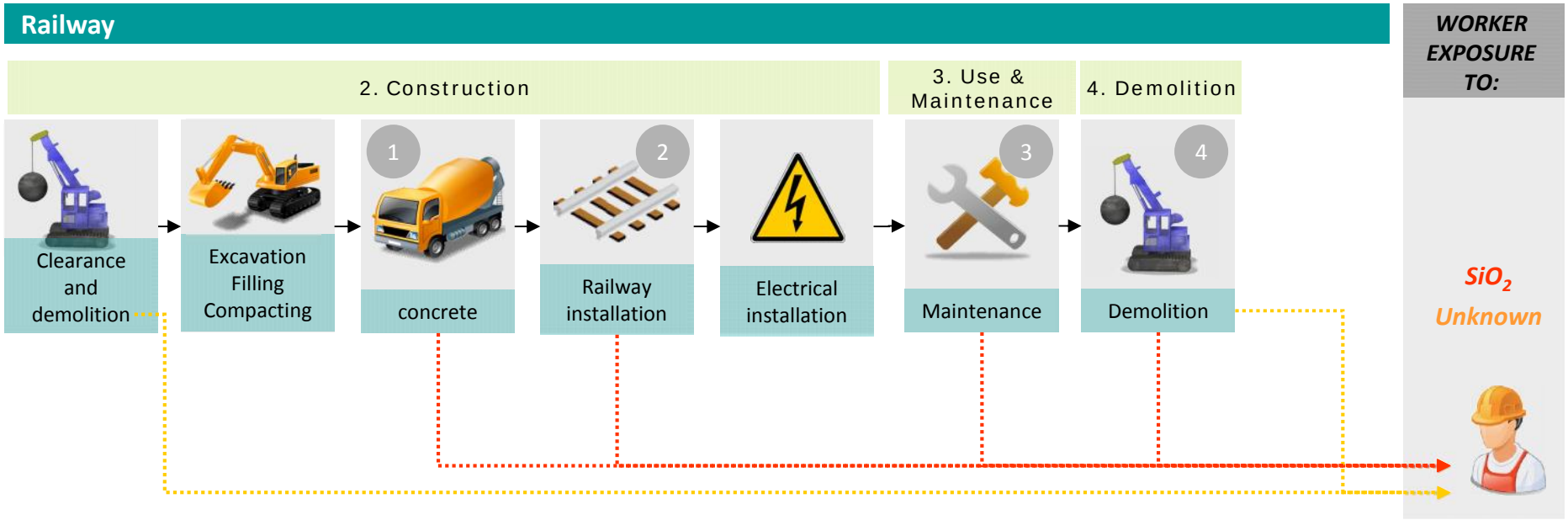
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **SiO_2** used in this process.

4) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **SiO_2**, Other.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Concrete	**ES7**:Concrete mixing for piles, slabs and special structures	SiO_2
	2. Railway installation	**ES8**:On-site assembly/machining	
3. **Maintenance**		**ES9**: Maintaining. Demolition or failure of the structure	
		ES10:Accidental fire: MNMs combustion	
4. **Demolition or dismantle**		**ES9**: Maintaining. Demolition or failure of the structure	

PROCESS: CIVIL – Transport Infrastructure - BRIDGE

In this process there are described the steps involved in BRIDGE construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Drainage. It is the construction of the drainage system. Here there is not release of particles.

b. Ironwork. It is the collocation of iron structure. Here there is not release of particles.

c. Concrete. It is the pouring of the concrete. The material is doped by **SiO_2** so it is considered this **nanomaterial release**.

e. Finishing. Finishing activities are considered tasks like polish, coating application… Here **other nanomaterial** could be released such as dust generated during polish activities.

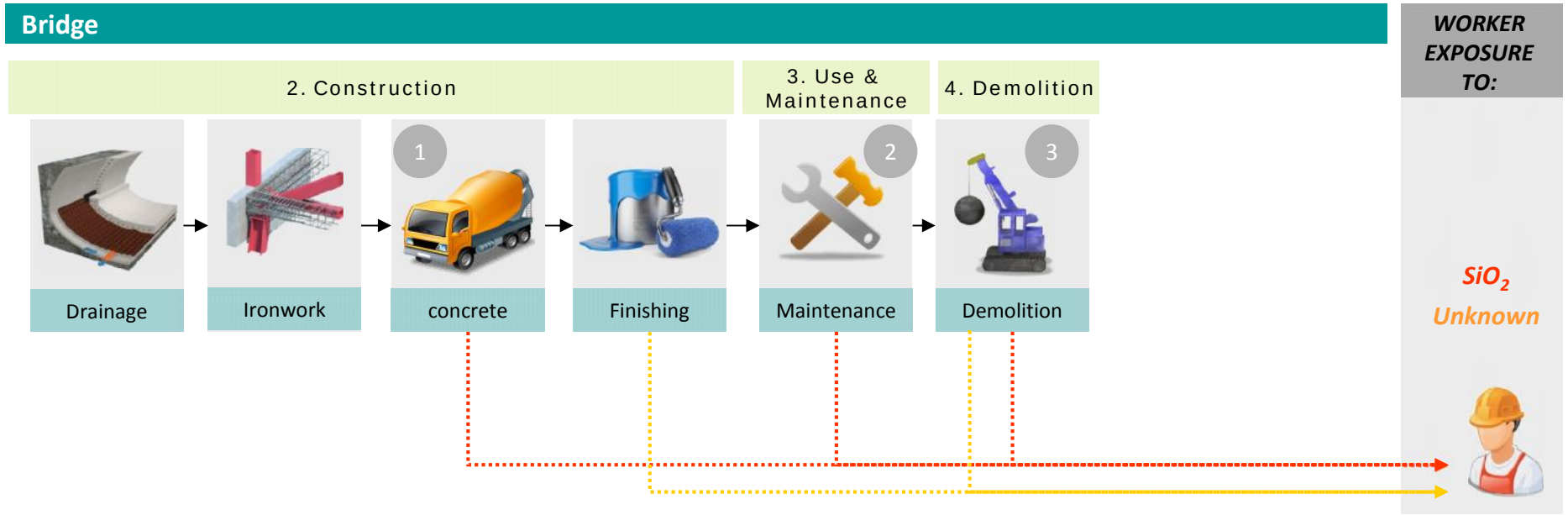
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **SiO_2** used in this process.

4) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **SiO_2**, Other.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Concrete	**ES7**:Concrete mixing for piles, slabs and special structures	SiO_2
		ES8:On-site assembly/machining	
2. **Maintenance**		**ES9**: Maintaining. Demolition or failure of the structure	
		ES10:Accidental fire: MNMs combustion	
3. **Demolition or dismantle**		**ES9**: Maintaining. Demolition or failure of the structure	

PROCESS: CIVIL – Transport Infrastructure - TUNNEL

In this process there are described the steps involved in TUNNEL construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Drainage. It is the construction of the drainage system. Here there is not release of particles.

b. Excavation, demolition, explosion. Demolition and explosion operations will release **other** nanoparticle of dust.

c. Shortcrete or anchorage. Shotcrete is concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. The material is doped by **CNF** or **NC** so it is considered this nanomaterial release.

d. Installations: ventilation, wiring, accesses. Ventilation, wiring…activities implies operations like machining of the concrete previously conveyed, so it will be released dust doped by **CNF** or **NC**.

e. Upside infrastructure. These are operations related to the construction of de outside of the tunnel (i.e. the frontage). The activities into this task could generate the release of **other** particles.

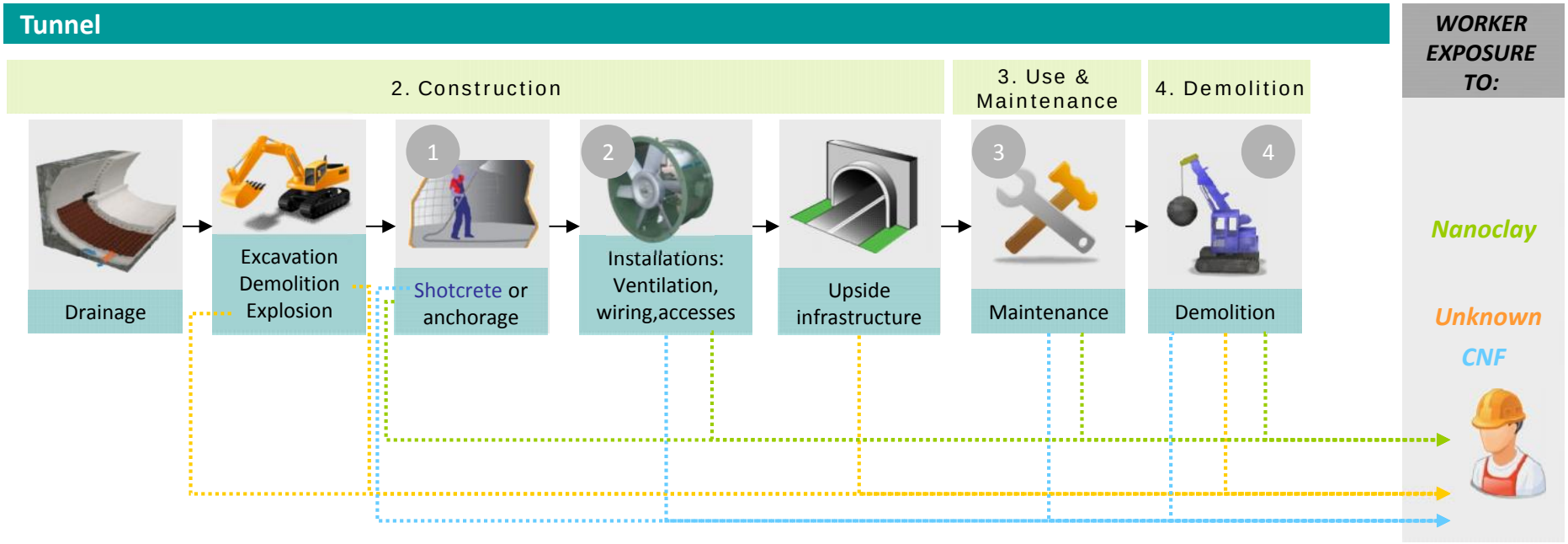
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **CNF** or **NC** used in this process.

4) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **CNF** or **NC** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **CNF**, **NC,** Other.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Shotcrete	ES11/ ES11:Manufacture in-site pavements	CNF, NC[5]
	2. Installations	ES12/ ES12:Machinig for superfitial fitting	
3. **Maintenance**		ES13/ ES13: Maintenance or demolition of the road surface	
		ES14/ ES14:Accidental fire: MNMs combustion	
4. **Demolition or dismantle**		ES13/ ES13: Maintenance or demolition of the road surface	

[5] The NC is considered in this process due to the experience of ACCIONA in the use of Nanoclays in asphalts.

PROCESS: CIVIL – Transport Infrastructure - HARBOR

In this process there are described the steps involved in HARBOR construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Foundation laying. It is the pouring of the concrete into the molds previously constructed and established. The concrete is doped by **SiO_2** so it is considered this **nanomaterial release**.

b. Elements assembling. This step requires the machining of elements doped by **SiO_2.**

c. Formwork. Formwork is the term given to either temporary or permanent molds into which concrete or similar materials are poured. In this task there will not be any release of particle.

d. Concrete. During the pouring of the concrete it is possible to have release of **SiO_2**.

e. Compacting. The concrete will be compacted. No release of particle is considered.

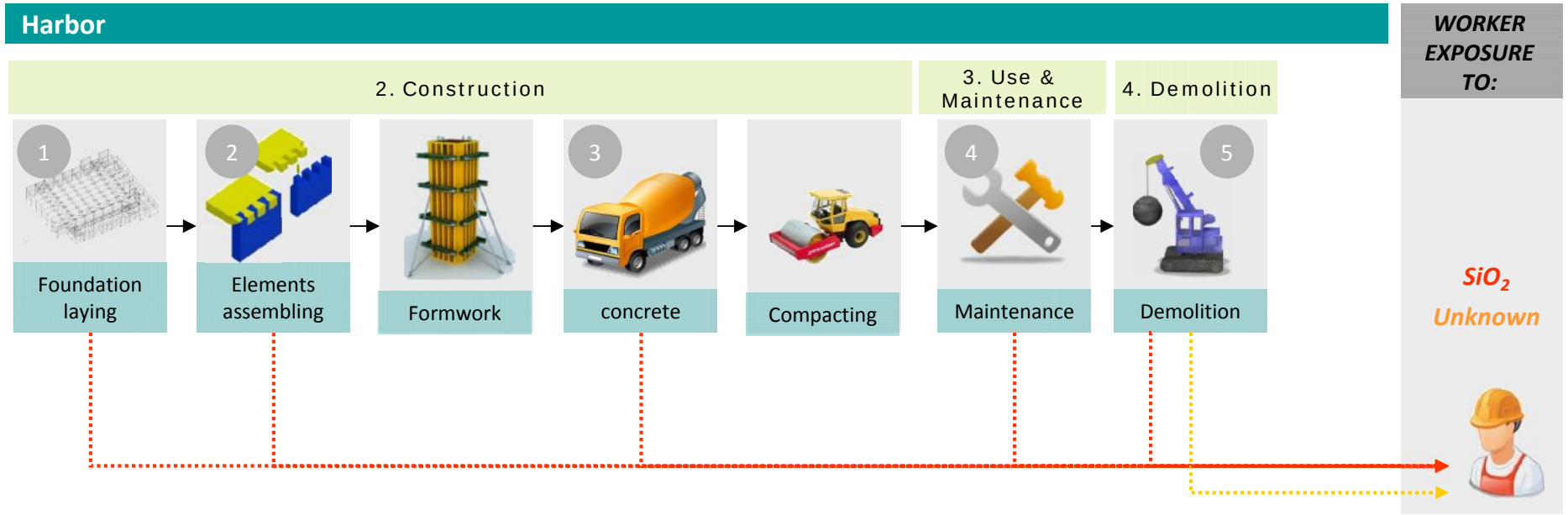
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **SiO_2** used in this process.

4) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **SiO_2**, Other.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Foundation laying	**ES7**:Concrete mixing for piles, slabs and special structures	SiO_2
	2. Elements assembling	**ES8**:On-site assembly/machining	
	3. Concrete	**ES7**: Concrete mixing for piles, slabs and special structures	
4. **Maintenance**		**ES9**: Maintaining, demolitions or failure of the structure	
		ES10:Accidental fire: MNMs combustion	
5. **Demolition or dismantle**		**ES9**: Maintaining, demolitions or failure of the structure	

PROCESS: CIVIL – Transport Infrastructure - AIRPORT

The construction of an airport is a combination between a road and a building construction previously described.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Clearance and demolition. It is the preparation of the soil before starting the edification. It is considered the demolition of the previous infrastructure and the cleaning of the soil. In this task would be **other nanomaterial release**.

Road

b. Excavation, filling, compacting. It is the preparation of the soil before starting pouring the road material. In this task there is not considered any nanomaterial release.

c. 1.Grouting. It is the pouring of the road material. The material is doped by **TiO_2** so it is considered this **nanomaterial release**.

d. 2.1. Bituminous road. This task the road material will be poured. The poured material is a bituminous road containing **CellNF** and **NC**, so it is consider a release of these particles.

e. 2.2. Compacting. During the compacting it is not considered any MNM release.

Building

f. Formwork and concrete. It is the construction and the establishment of the molds where the concrete is going to poured in. In this task there will not be any nanomaterial release.

g. Foundation laying. It is the pouring of the concrete into the molds. The concrete is doped by **SiO_2** so it is considered this **nanomaterial release**.

h. Insulations and Fire Retardant (FR) panels. This task is related to panel collocation either insulation panel or FR panels. Insulation and RF panels are doped with **CellNF** and **Nanoclay** respectively, so it is consider a release of these nanomaterials.

i. Iron works, walls, plumbing. It is regarding the installation of common facilities (plumbing, electricity…) and construction of walls. In this tasks wall doped with **TiO_2** so it is consider the **release** of these particles.

j. Finishing, paint, polish. Here are the tasks related to finishing operations such as surface painting or polishing. i.e. wall painting. In this task would be **other nanomaterial release**.

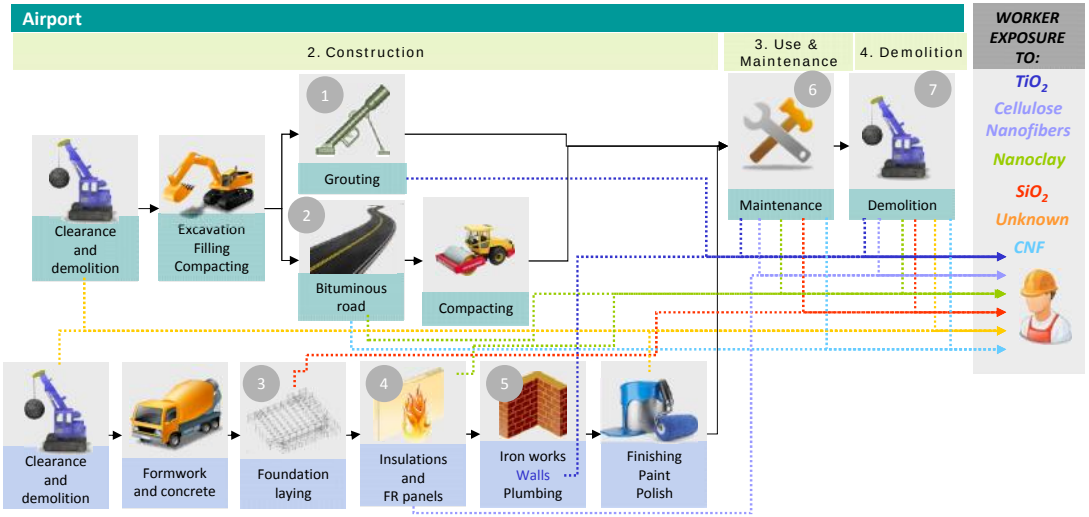
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **TiO_2**, **CellNF**, **NC** and **SiO_2**.

4) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **TiO_2**, **CellNF**, **NC** and **SiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **TiO_2**, **CellNF**, **NC**, **SiO_2**, Other.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Grouting	**ES15**:Preparation, dosification and application	**TiO_2**
		ES16: Superficial machining	
	2. Bituminous road	ES11/ES11:Manufacture in-site of the pavements	CNF, NC[6]
		ES12/ES12:Machining for superficial fitting of other elements	
	3. Foundation laying	**ES7**:Concrete mixing piles, slabs and special structures	**SiO_2**
		ES8:On- site assembly/machining	
	4. Insulations and FR panels	ES19/ES23:Off-site manufacturing → *not considered in the project*	CellNF, NC
		ES20/ES24:Fitting of the panels and machining for the superficial installations of other elements	
	5. Walls	**ES2**:Monolayer rendering application	**TiO_2**
		ES3:On site assembly/machining	
6. **Maintenance**		**ES5**/ **ES10**/ ES14/ ES14/**ES18**/ES22/ES26:Accidental fire: MNM combustion	CellNF, NC, **TiO_2**, **SiO_2** CNF
7. **Demolition or dismantle**		**ES4**/ **ES9**/ ES13/ ES14/**ES17**/ES21/ES25:Demolition, end of life	

[6] The NC is considered in this process due to the experience of ACCIONA in the use of Nanoclays in asphalts.

PROCESS: CIVIL – Transport Infrastructure - METROPOLITAN

The construction of a metropolitan is a combination between a tunnel and a railway construction previously described.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

Tunnel

a. Drainage. It is the construction of the drainage system. Here there is not release of particles.

b. Excavation, demolition, explosion. Demolition and explosion operations will release **other** nanoparticle of dust.

c. Shortcrete or anchorage. Shotcrete is concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. The material is doped by **CNF** or **NC** so it is considered this nanomaterial release.

d. Installations: ventilation, wiring, accesses. Ventilation, wiring…activities implies operations like machining of the concrete previously conveyed, so it will be released dust doped by **CNF** or **NC**.

e. Upside infrastructure. These are operations related to the construction of the outside of the tunnel (i.e. the frontage). In this activity could be the generation of **other** particles.

Railway

a. Clearance and demolition. It is the preparation of the soil before starting the edification. It is considered the demolition if the previous infrastructure and the cleaning of the soil. In this task would be **other nanomaterial release**.

b. Excavation, filling, compacting. It is the preparation of the soil before starting the pouring of the concrete. In this task there is not considered any nanomaterial release.

c. Concrete. It is the pouring of the concrete. The material is doped by **SiO_2** so it is considered this **nanomaterial release**.

d. Railway installation. In this task will be machining operations that will generate **SiO_2** dust.

e. Electrical installation. Electrical installation will not generate any nanoparticle release.

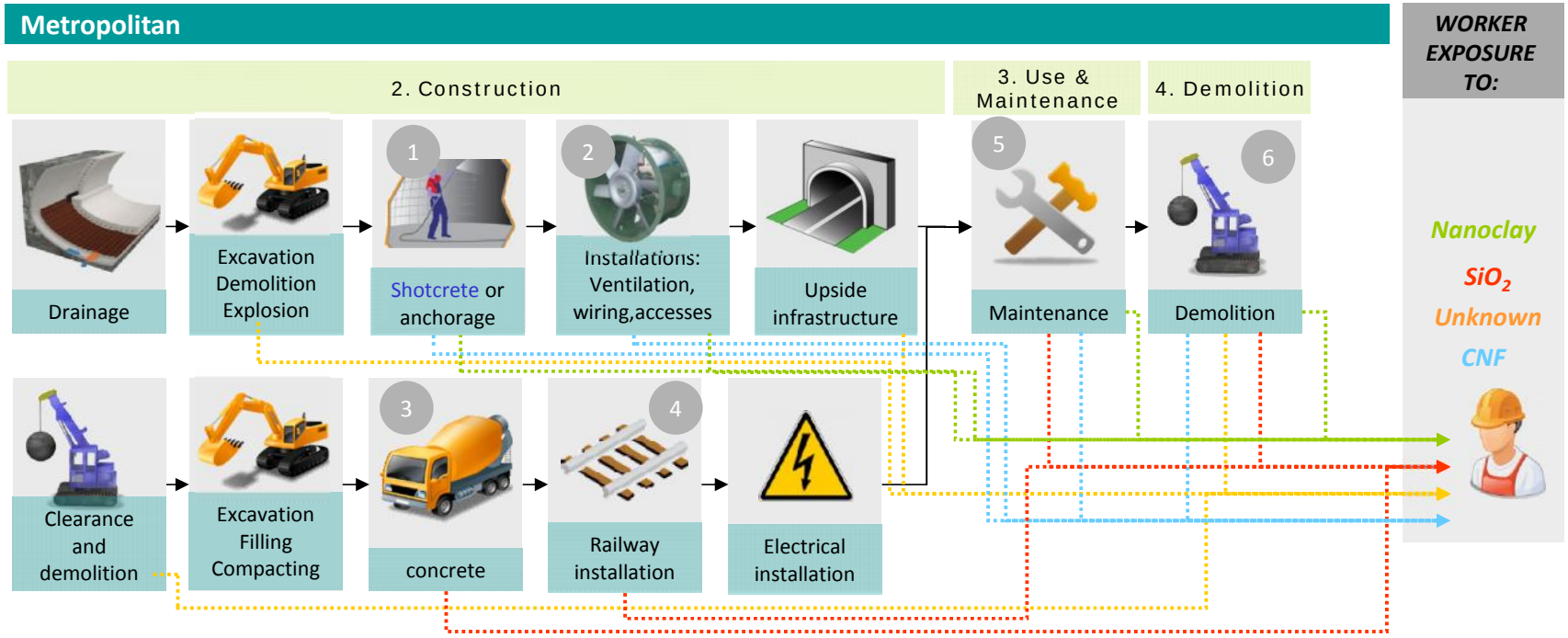
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **CNF** or **NC** and **SiO_2**.

4) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **CNF** or **NC** and **SiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **CNF**, **NC, SiO_2**, Other.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Shotcrete	ES11/ES11:Manufacture in-site pavements	CNF, NC[7]
	2. Installation	ES12/ES12:Machining for superficial fitting	
	3. Concrete	ES7:Concrete mixing for piles, slabs and special structures	SiO_2
	4. Railway installation	ES8:On-site assembly/machining	
5. **Maintenance**		ES9/ES13/ES13: Maintenance or demolition	CNF, NC, SiO_2
		ES10/ ES14/ES14:Accidental fire: MNM combustion	
6. **Demolition or dismantle**		ES9/ES13/ES13: Maintenance or demolition	

[7] The NC is considered in this process due to the experience of ACCIONA in the use of Nanoclays in asphalts.

PROCESS: CIVIL – Hydraulic – DAMS AND LEVEES

In this process there are described the steps involved in DAMS AND LAVEES construction, which are the same as in the HARBOR construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Foundation laying. It is the pouring of the concrete into the molds previously constructed and established. The concrete is doped by **SiO_2** so it is considered this **nanomaterial release**.

b. Elements assembling. This step requires the machining of elements doped by **SiO_2.**

c. Formwork. Formwork is the term given to either temporary or permanent molds into which concrete or similar materials are poured. In this task there will not be any release of particle.

d. Concrete. During the pouring of the concrete it is possible to have release of **SiO_2**.

e. Compacting. The concrete will be compacted. No release of particle is considered.

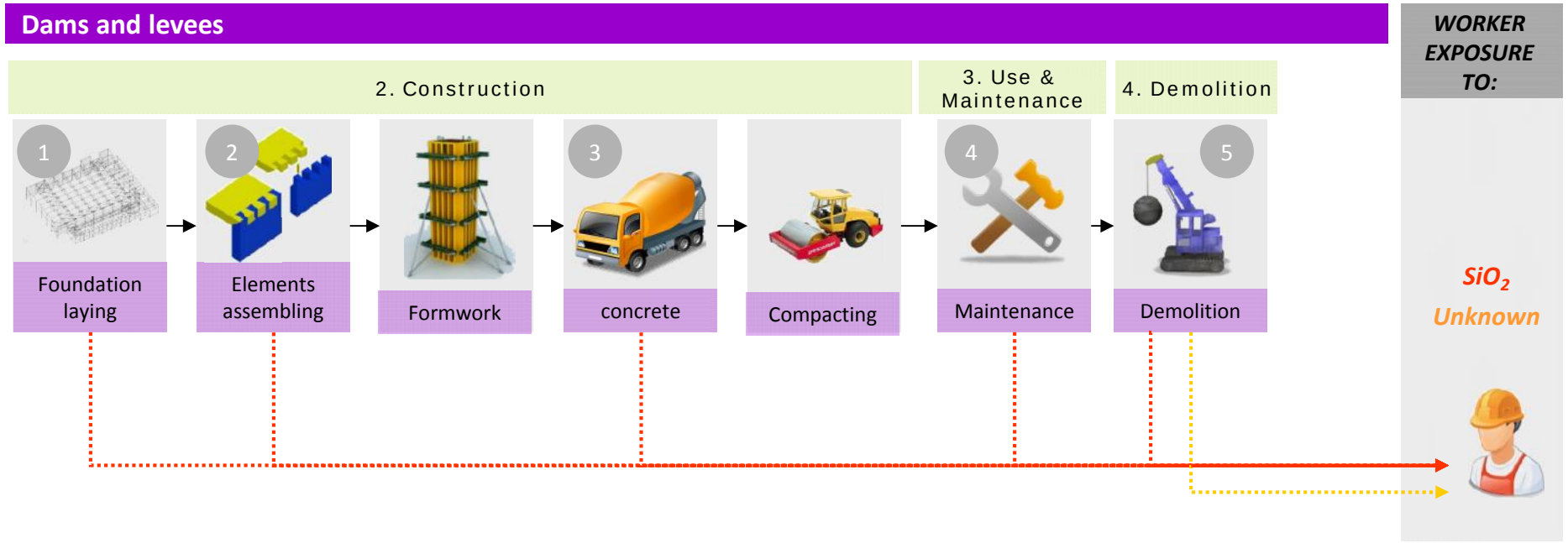
5) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **SiO_2** used in this process.

6) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **SiO_2**, Other.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Foundation laying	**ES7**:Concrete mixing for piles, slabs and special structures	SiO_2
	2. Elements assembling	**ES8**:On-site assembly/machining	
	3. Concrete	**ES7**: Concrete mixing for piles, slabs and special structures	
4. **Maintenance**		**ES9**: Maintaining, demolitions or failure of the structure	
		ES10:Accidental fire: MNMs combustion	
5. **Demolition or dismantle**		**ES9**: Maintaining, demolitions or failure of the structure	

PROCESS: CIVIL – Hydraulic – CHANNEL AND SEWAGE

In this process there are described the steps involved in CHANNEL AND SEWAGE construction, which are the same as in the TUNNEL construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Drainage. It is the construction of the drainage system. Here there is not release of particles.

b. Excavation, demolition, explosion. Demolition and explosion operations will release **other** nanoparticle of dust.

c. Shortcrete or anchorage. Shotcrete is concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. The material is doped by **CNF** or **NC** so it is considered this nanomaterial release.

d. Installations: ventilation, wiring, accesses. Ventilation, wiring…activities implies operations like machining of the concrete previously conveyed, so it will be released dust doped by **CNF**.

e. Upside infrastructure. These are operations related to the construction of de outside of the tunnel (i.e. the frontage). The activities into this task could generate the release of **other** particles.

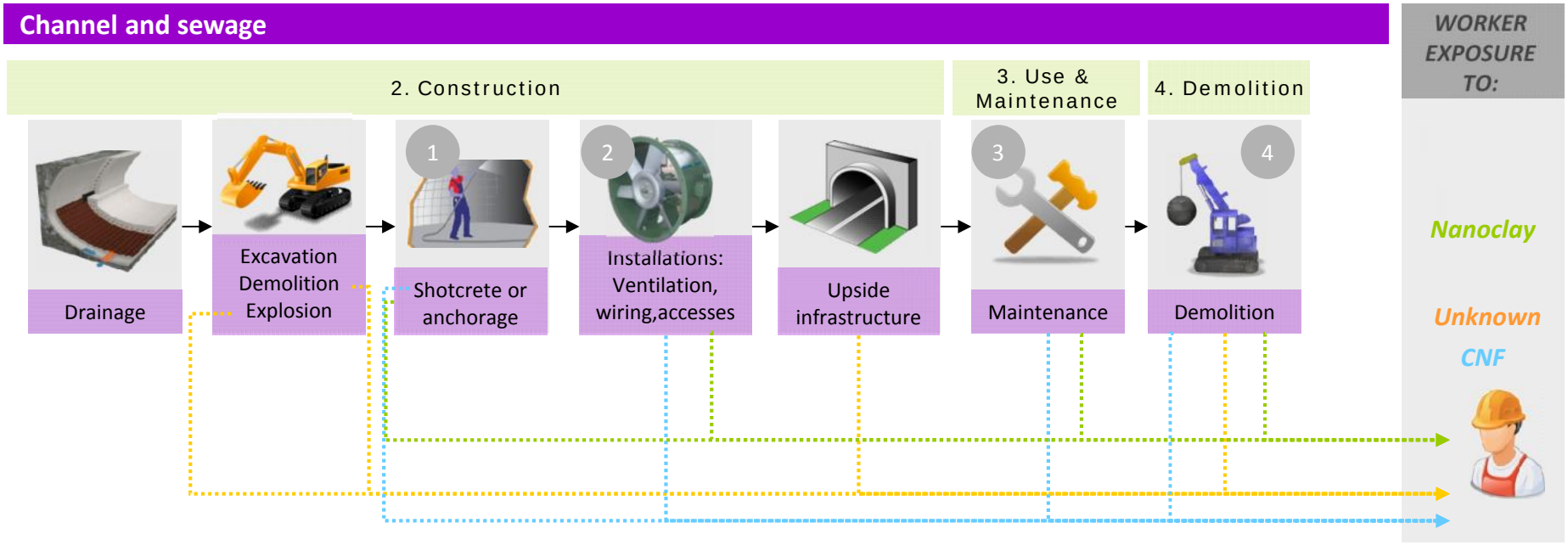
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of the nanoproducts made by **CNF** or **NC** used in this process.

4) **Demolition or dismantle.** Demolition, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **CNF** or **NC** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **CNF**, **NC**, **Other**.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Shotcrete	ES11/**ES11**:Manufacture in-site pavements	CNF, NC[8]
	2. Installations	ES12/**ES12**:Machinig for superfitial fitting	
3. **Maintenance**		ES13/**ES13**: Maintenance or demolition of the road surface	
		ES14/**ES14**:Accidental fire: MNMs combustion	
4. **Demolition or dismantle**		ES13/**ES13**: Maintenance or demolition of the road surface	

[8] The NC is considered in this process due to the experience of ACCIONA in the use of Nanoclays in asphalts.

PROCESS: CIVIL – Hydraulic – HYDROELECTRIC PLANTS

In this process there are described the steps involved in HYDROELECTRIC PLANTS construction, which are the same as in the BUILDING construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Clearance and demolition. It is the preparation of the soil before starting the edification. It is considered the demolition if the previous building and the cleaning and preparation of the soil. In this task would be **other nanomaterial release**.

b. Formwork and concrete. It is the construction and the establishment of the molds where the concrete is going to poured in. In this task there is not considered any nanomaterial release.

c. Foundation laying. It is the pouring of the concrete into the molds previously constructed and established. The concrete is doped by **SiO_2** so it is considered this **nanomaterial release**.

d. Insulations and Fire Retardant (FR) panels. This task is related to panel collocation either insulation panel or FR panels. Insulation and RF panels are doped with **CellNF** and **Nanoclay** respectively, so it is consider a release of these nanomaterials during the collocation process.

e. Iron works, walls, plumbing. It is regarding the installation of common facilities (plumbing, electricity…) and construction of walls. In this tasks wall doped with **TiO_2** so it is consider the **release** of these particles.

f. Finishing, paint, polish. Here are the tasks related to finishing operations such as painting or polishing of the surfaces. i.e. wall painting. In this task would be **other nanomaterial release**.

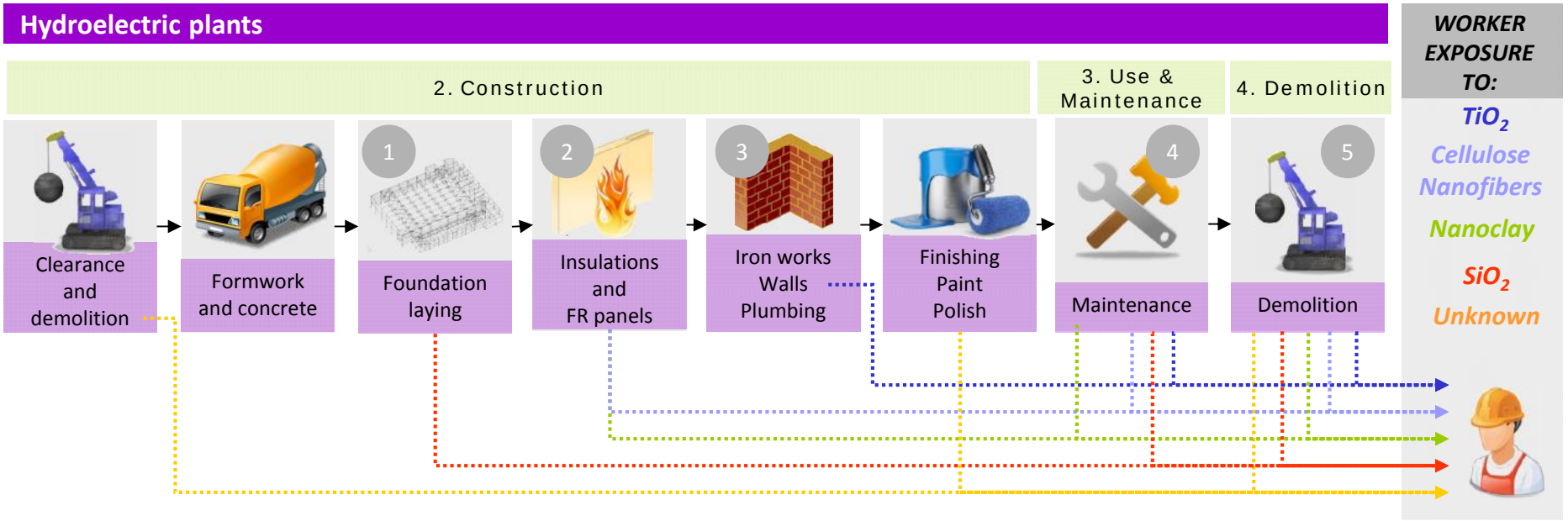
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2**, **CellNF**, **Nanoclay** and **TiO_2** MNMs.

4) **Demolition or dismantle.** Demolition of the whole building, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2**, **CellNF**, **Nanoclay, TiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **TiO_2**, **SiO_2**, **CellNF**, **Nanoclay**, **Other**.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	1. Foundation laying	**ES7**:Concrete mixing piles, slabs and special structures	SiO_2
		ES8:On- site assembly/machining	
	2. Insulations and FR panels	ES19/ES23:Off-site manufacturing → *not considered in the project*	NC CellNF
		ES20/ES24:Fitting of the panels and machining for the superficial instalations of other elements	
	3. Walls	**ES2**:Preparaton, dosification of coatings	TiO_2
		ES3:Application of coatings, superficial machining	
4. **Maintenance**		**ES10**/**ES5**/ES22/ES26:Accidental fire: MNM combustion	SiO_2 TiO_2 NC CellNF
5. **Demolition or dismantle**		**ES9**/**ES4**/ES21/ES25:Demolition, end of life	

PROCESS: CIVIL – Hydraulic – WATER TREATMENT PARTS

In this process there are described the steps involved in WATER TREATMENT PLANTS construction, which are the same as in the BUILDING construction.

1. STEPS INVOLVED IN THIS TASK

1) Design. *Out of the scope of the project.*

2) Operation or construction

a. Clearance and demolition. It is the preparation of the soil before starting the edification. It is considered the demolition if the previous building and the cleaning and preparation of the soil. In this task would be **other nanomaterial release**.

b. Formwork and concrete. It is the construction and the establishment of the molds where the concrete is going to poured in. In this task there is not considered any nanomaterial release.

c. Foundation laying. It is the pouring of the concrete into the molds previously constructed and established. The concrete is doped by **SiO_2** so it is considered this **nanomaterial release**.

d. Insulations and Fire Retardant (FR) panels. This task is related to panel collocation either insulation panel or FR panels. Insulation and RF panels are doped with **CellNF** and **Nanoclay** respectively, so it is consider a release of these nanomaterials during the collocation process.

e. Iron works, walls, plumbing. It is regarding the installation of common facilities (plumbing, electricity…) and construction of walls. In this tasks wall doped with **TiO_2** so it is consider the **release** of these particles.

f. Finishing, paint, polish. Here are the tasks related to finishing operations such as painting or polishing of the surfaces. i.e. wall painting. In this task would be **other nanomaterial release**.

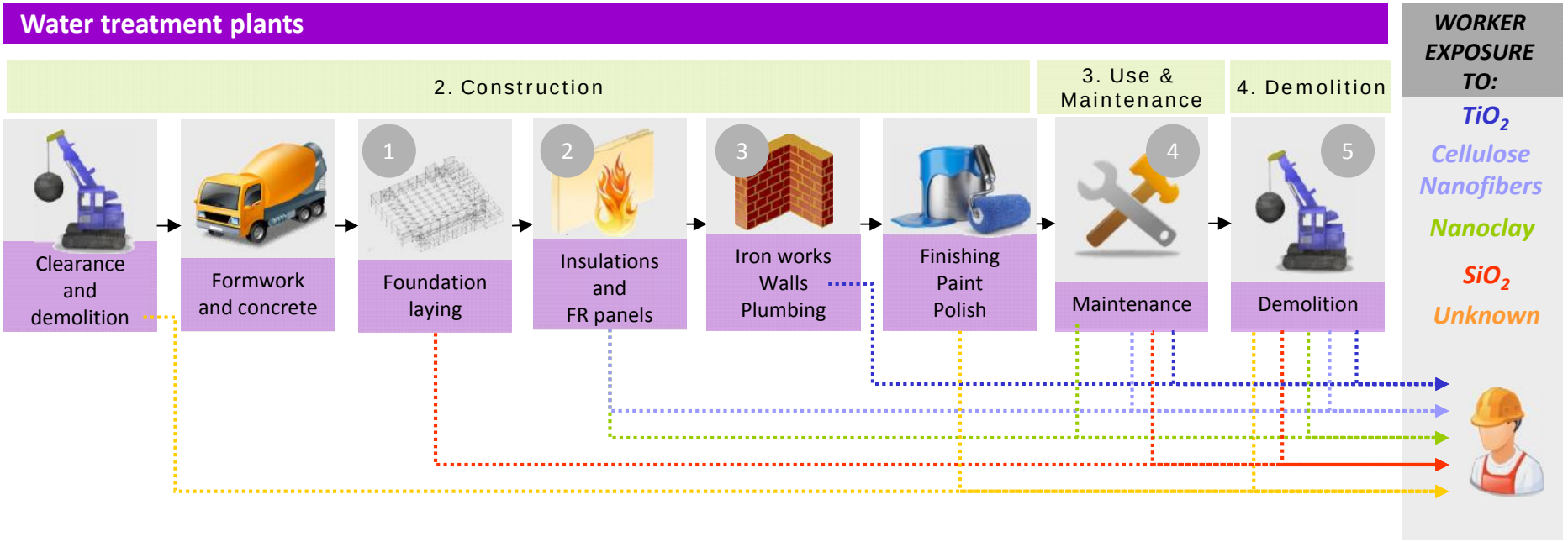
3) Maintenance. In this task are considered operations like cleaning, drilling (plumbing changes, electrical installation maintenance…), machining… This task implies the maintenance tasks of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2**, **CellNF**, **Nanoclay** and **TiO_2** MNMs.

4) **Demolition or dismantle.** Demolition of the whole building, the end of life. This task implies the demolition of all the nanoproducts used in this process. Therefore, there will be the release of **SiO_2**, **CellNF**, **Nanoclay, TiO_2** MNMs and also **other** kind of nanoparticles because of the dust generated during this task.

2. NANOMATERIAL INVOLVED IN THE PROCESS

The MNMs involved in the building process are: **TiO_2**, **SiO_2**, **CellNF**, **Nanoclay**, **Other**.

3. NANOMATERIAL FLOW



4. EXPOSURE SCENARIOS INVOLVED IN THE PROJECT

LIFE CYCLE STEPS		EXPOSURE SCENARIO	MNM
Operation or construction	6. Foundation laying	**ES7**:Concrete mixing piles, slabs and special structures	SiO_2
		ES8:On- site assembly/machining	
	7. Insulations and FR panels	ES19/ES23:Off-site manufacturing → *not considered in the project*	NC CellNF
		ES20/ES24:Fitting of the panels and machining for the superficial instalations of other elements	
	8. Walls	**ES2**:Preparaton, dosification of coatings	TiO_2
		ES3:Application of coatings, superficial machining	
9. **Maintenance**		**ES10**/**ES5**/ES22/ES26:Accidental fire: MNM combustion	SiO_2 TiO_2 NC CellNF
10. **Demolition or dismantle**		**ES9**/**ES4**/ES21/ES25:Demolition, end of life	

7. CONCLUSIONS

The main conclusion is that many processes are related to same ES, so it is possible to analyze ES which are related to different processes. In fact, the analysis of less ES is required reducing for instance the quantity of measurements to be carried out.

Next table shows the relationship between ES and the processes.

ES	PROCESS												
			Civil										
			Transport-infrastructure							Hydraulic			
	Manufacturing NMs	**Building**	Road	Railway	Bridge	Tunnel	Harbor	Airport	Metropolitan	Dams and lavees	Channel and sewage	Hydroelectric plants	Water treatment plants
ES1(TiO_2) **ES6**(SiO_2)	X												
ES2(TiO_2) **ES3**(TiO_2) **ES4**(TiO_2) **ES5**(TiO_2)		X						X				X	X
ES19*(Nanoclay)* **ES20***(Nanoclay)* **ES21***(Nanoclay)* **ES22***(Nanoclay)*		X						X				X	X
ES23*(CellNF)* **ES24***(CellNF)* **ES25***(CellNF)* **ES26***(CellNF)*		X						X				X	X
ES7(SiO_2) **ES8**(SiO_2) **ES9**(SiO_2) **ES10**(SiO_2)		X		X	X		X	X	X	X		X	X
ES11*(Nanoclay)*/ **ES11***(CNF)* **ES12***(Nanoclay)*/ **ES12***(CNF)* **ES13(***Nanoclay)*/ **ES13***(CNF)* **ES14***(Nanoclay)*/ **ES14***(CNF)*			X			X		X	X		X		
ES15(TiO_2) **ES16**(TiO_2) **ES17**(TiO_2) **ES18**(TiO_2)			X					X					

Table 4 Summary of ES to be analyzed in each process

Other conclusion obtained is about the condition of the NM that can be in different condition depending on the operation carried out. For example, most of the ES are focalized in the step 3 of the LC. The ES regarding this step are related to:

- Mixing compounds when the NM is in dust condition
  → Exposure to dust
- Mixture application (the NM is embedded in a viscous material)
  → Exposure to liquid embedded with NMs
- Machining, assembly,…tasks
  → Exposure to dust embedded with NMs

The ES related to maintenance are related to:

- Accidental fire
  → Exposure to fumes which can transport NMs particles of any nature

The ES related to dismantle are related to:

- End of life/demolition
  → Exposure to dust embedded with NMs

8. LIST OF TABLES AND FIGURES

FIGURES

TABLES

9. REFERENCES

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