Life Cycle Assessment of a nanoTiO_2 glazed steel panel

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in collaboration with

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Overview

ARACNE www.aracne.emr.it

- **Italian project**

✓ 3 companies of Emilia-Romagna (suppliers of building industries)

✓ University of Modena and Reggio Emilia

✓ University of Bologna

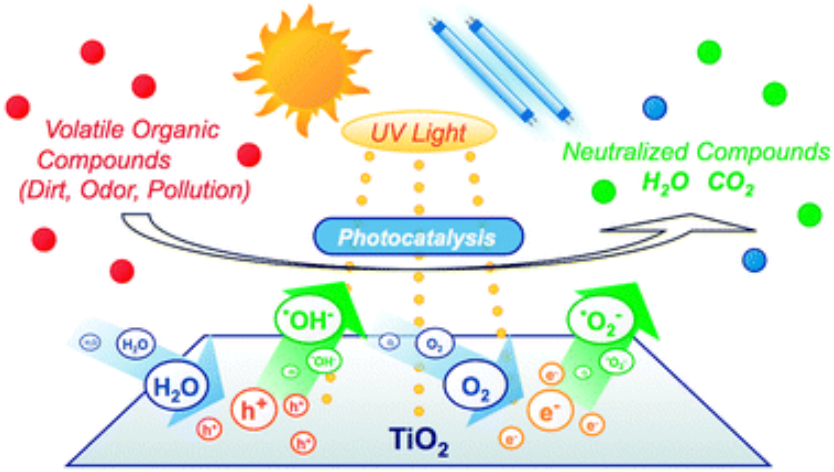
- **study new building materials** with higher technological properties obtained by the addition of TiO_2 nanomaterials

The most important properties about TiO_2

photo – induced redox reaction of adsorbed substances

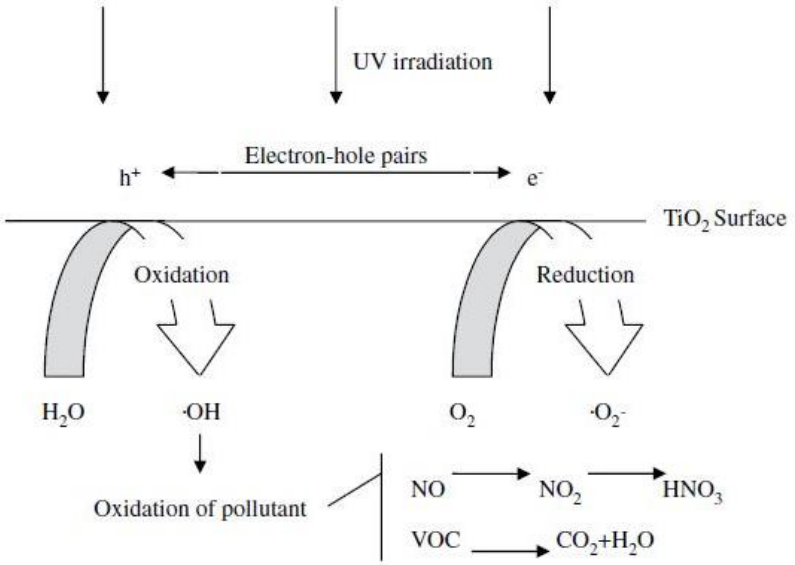
+

photo – induced super hydrophilicity



- ✓ Air depollution
- ✓ Self-cleaning
- ✓ Self-disinfecting
- ✓ Self-sterilizing
- ✓ Anti-fogging

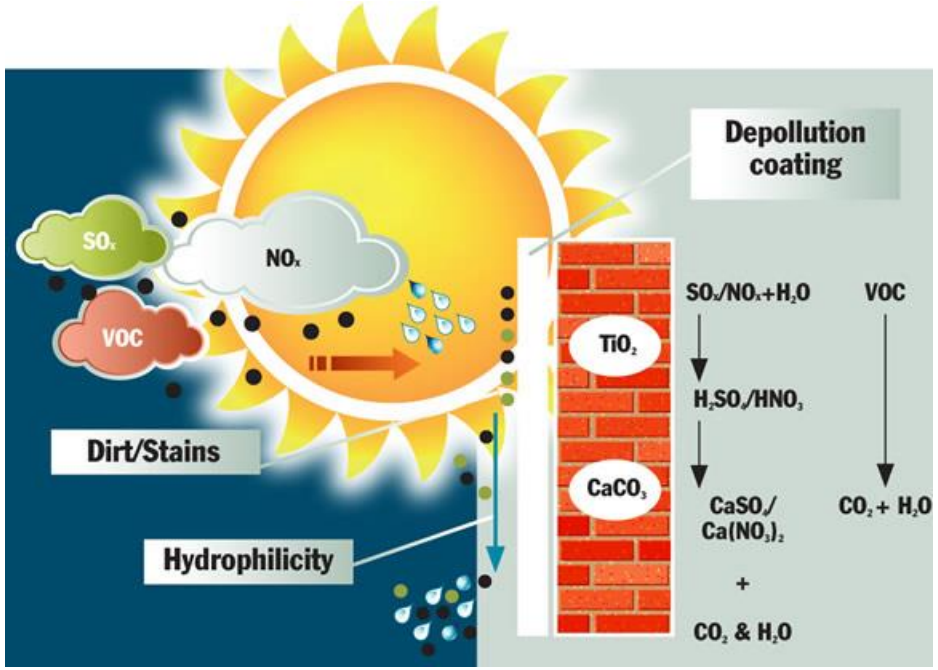
Air depollution (outdoor and indoor)



Pollution removal mechanism of TiO_2 photocatalysis

Source: J. Chen, C.-sun Poon / Building and Environment 44 (2009) 1899–1906

Self-cleaning nanoTiO_2 coatings



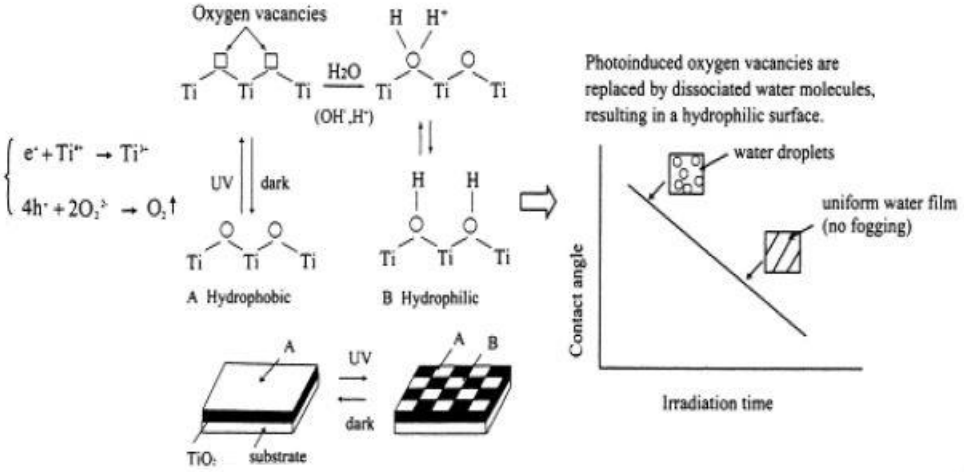


Photo-induced hydrophylic TiO_2 surface

Source: J. Chen, C.-sun Poon / Building and Environment 44 (2009) 1899–1906

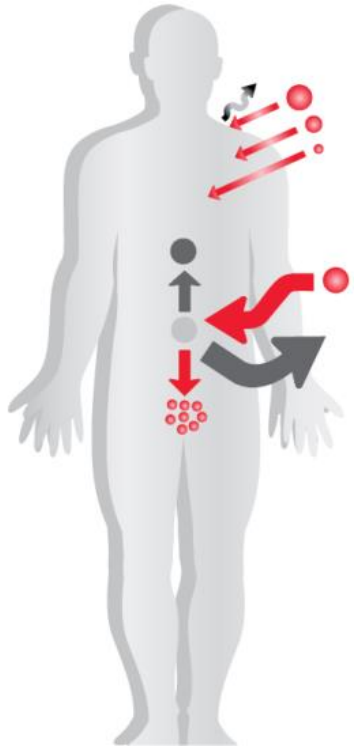
NanoTiO$_2$: toxic or harmless?

Uncertainties and knowledge gaps

on behavior and toxicity of nanoparticles :

preliminary attempt to introduce in LCIA the damage on human health generated by titania nanoparticles emissions to air

References	
NIOSH *National Institute for Occupational Safety and Health*	**0.3 mg/m^3 = occupational exposure limits for ultrafine TiO$_2$** (concentration that would be sufficient to reducing the risk of lung tumors to a 1/1000 lifetime excess risk level)
IARC *International Agency for Research on Cancer*	**TiO$_2$ in Group 2B = "possibly carcinogenic to humans"** (sufficient evidence of carcinogenicity in experimental animals and inadequate evidence of carcinogenicity in humans)



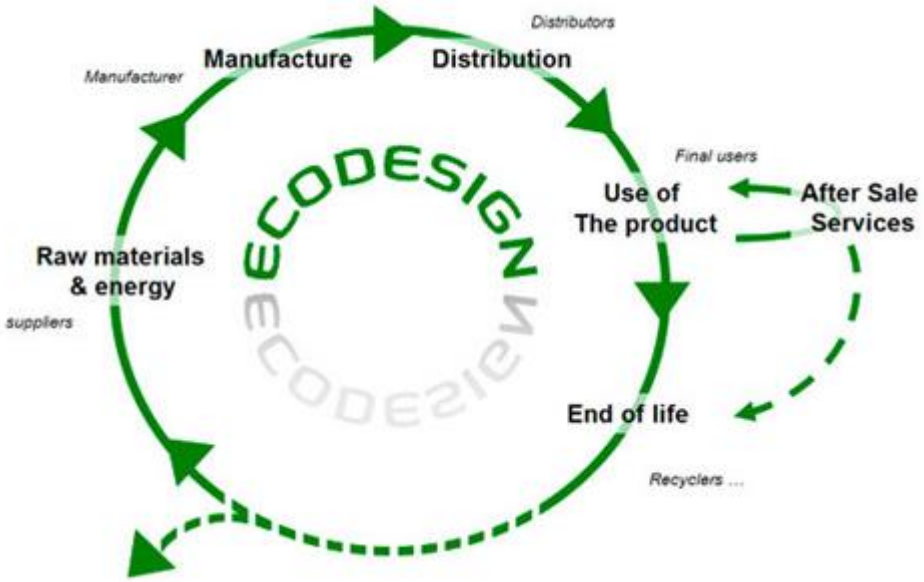
Source: *1° SEMINARIO TECNICO - Il contributo del dipartimento di scienze e metodi dell'ingegneria nello sviluppo del Life Cycle Assessment (LCA) per la gestione della sostenibilità ambientale – 18-09-2013*

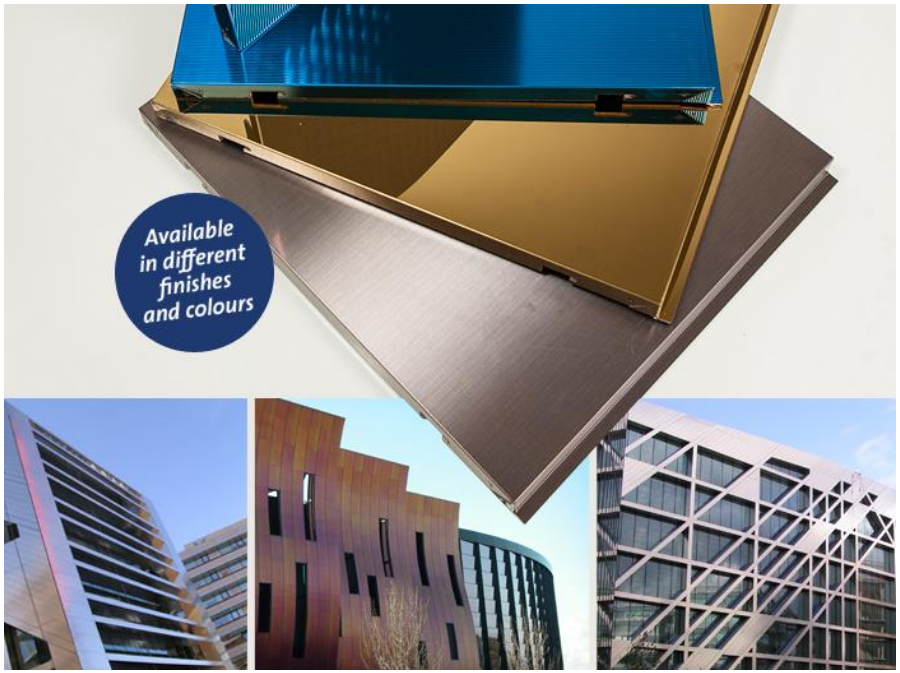
Pini M., Neri P., Montecchi R., Ferrari A.M., 247th ACS National Meeting & Exposition, Dallas, Texas, March 16-20, 2014, "Life Cycle Assessment of nanoTiO2 functionalized porcelainized stoneware tiles".

LCA study

of an industrial scale up for the production of

self-cleaning steel panel glazed with TiO_2 nanoparticles





Goal and scope definition

- **Studied system:** nanoTiO_2 glazed steel surface
- **System function:** self-cleaning and anti-smog external coating
- **Functional unit:** 1m^2 of glazed steel panel
- **Life span:** 20 years

Source: Superfici in smalto porcellanato nano-strutturate mediante applicazione di nanotitania, C.I.S.P. Centro Italiano Smalti Porcellanati, Smalto porcellanato-Tecnologia & Mercati" n.3, 2009.

- **System boundaries:** '*from cradle to grave*'
- **Data quality:** primary data and literature sources
- **Calculation software:** SimaPro 7.3.3
- **Impact assessment method:** **modified IMPACT 2002+**

Modified IMPACT 2002+

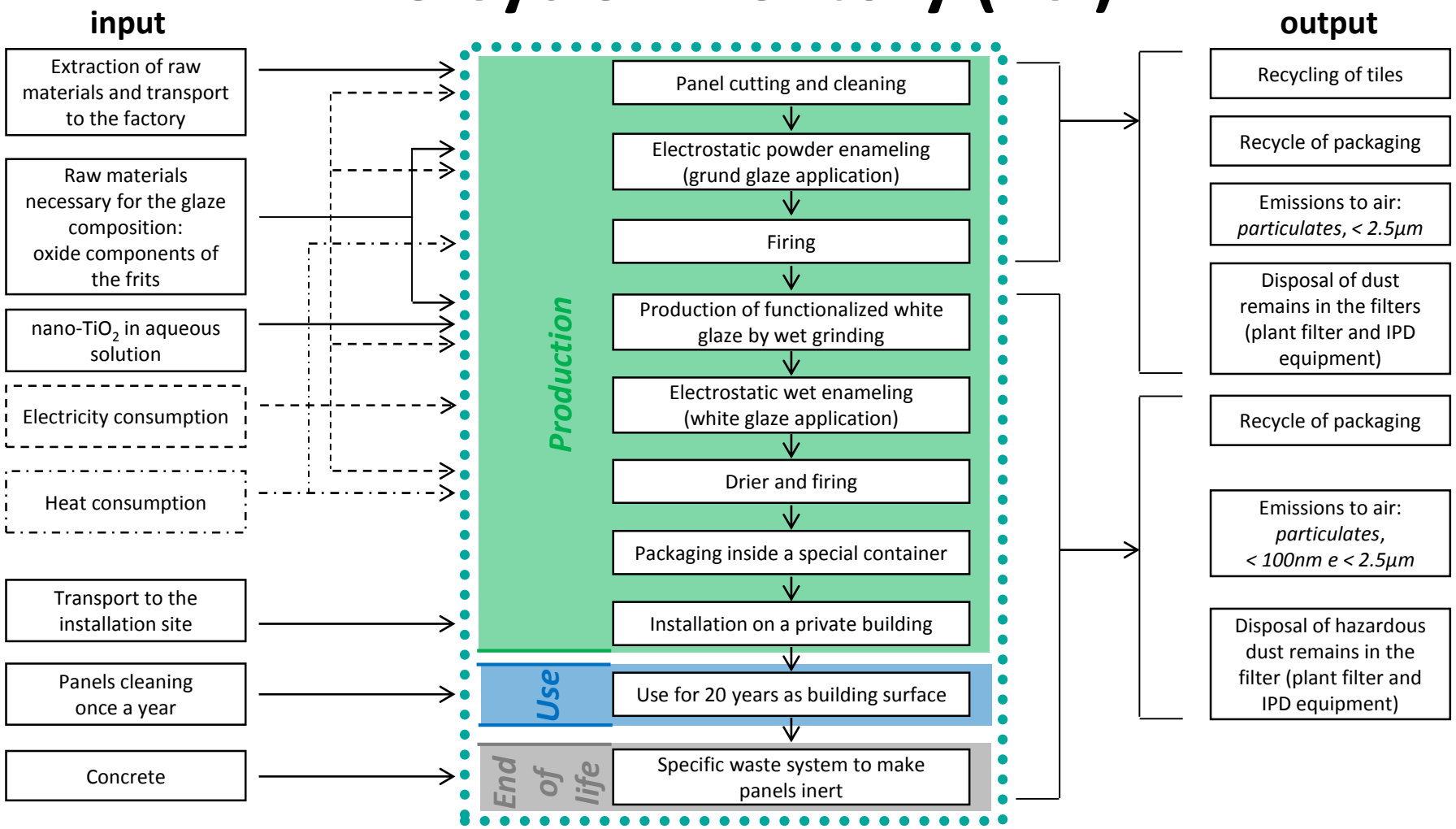
Determination of **damage to human health** caused by outdoor and indoor/inhaled nanoTiO_2 emissions

	Outdoor emissions	Indoor/Inhaled emissions
Characterization factor	0.109 kg $_{C2H3Cl}$/kg $_{nanoTiO_2}$	1kg $_{C2H3Cl}$/kg $_{nanoTiO_2}$
Damage assessment factor	2.8 E-6 DALY/kg*	5.5 DALY/kg
New substance	***Particulates, <100 nm***	***Particulates, <100 nm indoor/inhaled***
Impact category	Carcinogens*	**Carcinogens inhaled**
Damage category	Human Health*	**Carcinogens inhaled**
Data input	emissions not captured by air filter and emissions not inhaled by workers	emissions not captured by face mask and so inhaled by workers

** Unchanged with respect to IMPACT 2002+*

Source: *Life cycle assessment of nanoTiO_2 coated self-cleaning float glass, M.Pini, A.M.Ferrari, E.I.C.Gonzales, P.Neri, C.Siligardi / Proceeding of Nanotech 2013*

Life Cycle Inventory (LCI)



Ecodesign approach

- ✓ to define the potential damage of TiO_2 nanoparticles
  - ✓ **to minimize the environmental burdens**

Assumptions:

- HEPA (*High Efficiency Particulate Air filter):* 99,97% of efficiency
- PPE (*Personal Protective Equipment*): face mask with 95% of efficiency
- Closed manufacturing system
- Attention to final waste treatments

Assumptions on emissions

Estimation of nanoparticles emissions in all life cycle stage:

✓ 1%
production phase

- **1%** released into the production site → in part inhaled by the worker, the rest is released outdoor
- **99%** captured by the vacuum system
  - **99.97%** captured by HEPA filter
  - **0.03%** directly released in air

✓ 20%
use phase

- **1%** inhaled by the worker
- **99%** directly released in air

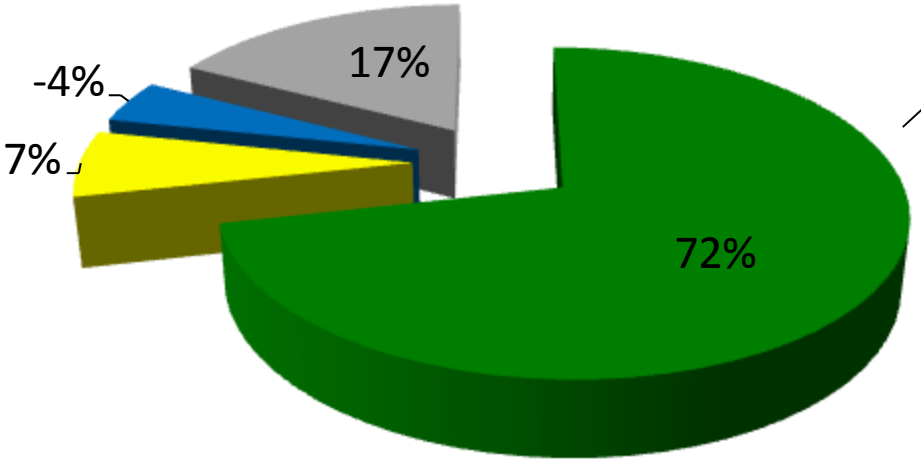
✓ 0,1%
end of life

- **1%** inhaled by the worker
- **99%** directly released in air

LCIA – Single score

1m² of a nano TiO_2 glazed steel panel

Total damage: 11,78 mPt



72% PRODUCTION:

63,31% Steel panel production

8,68% Electrostatic wet enameling (*white glaze application*)

2,43% Electrostatic powder enameling (*grund glaze application*)

PRODUCTION (9,243 mPt) INSTALLATION (0,871 mPt) USE (-0,57 mPt) END OF LIFE (2,235 mPt)

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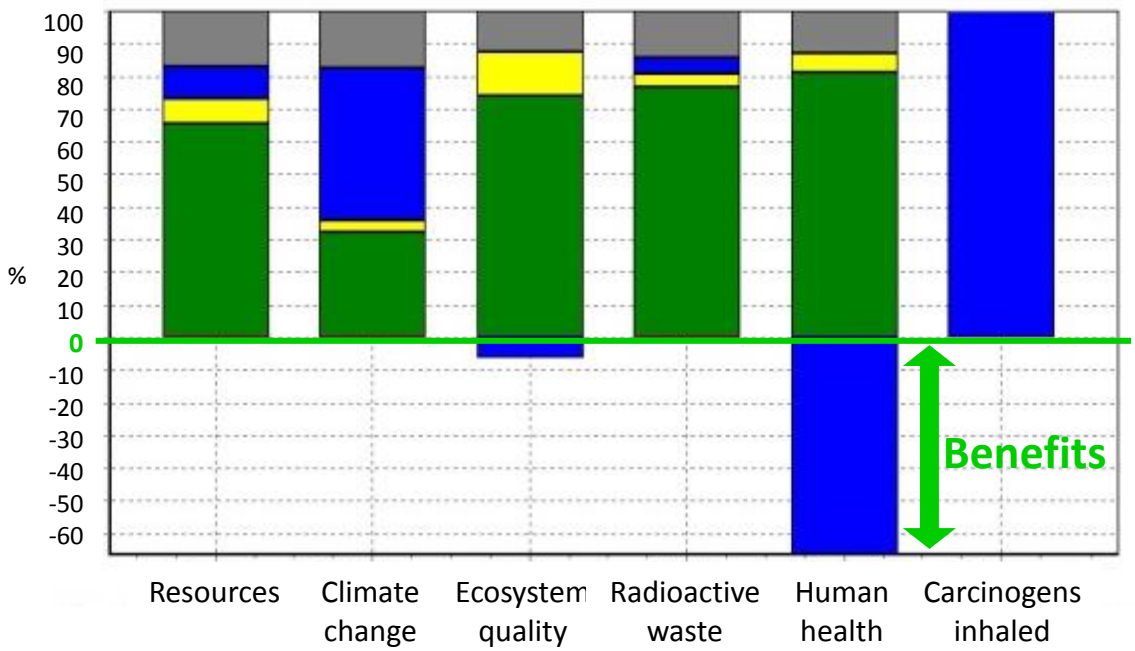

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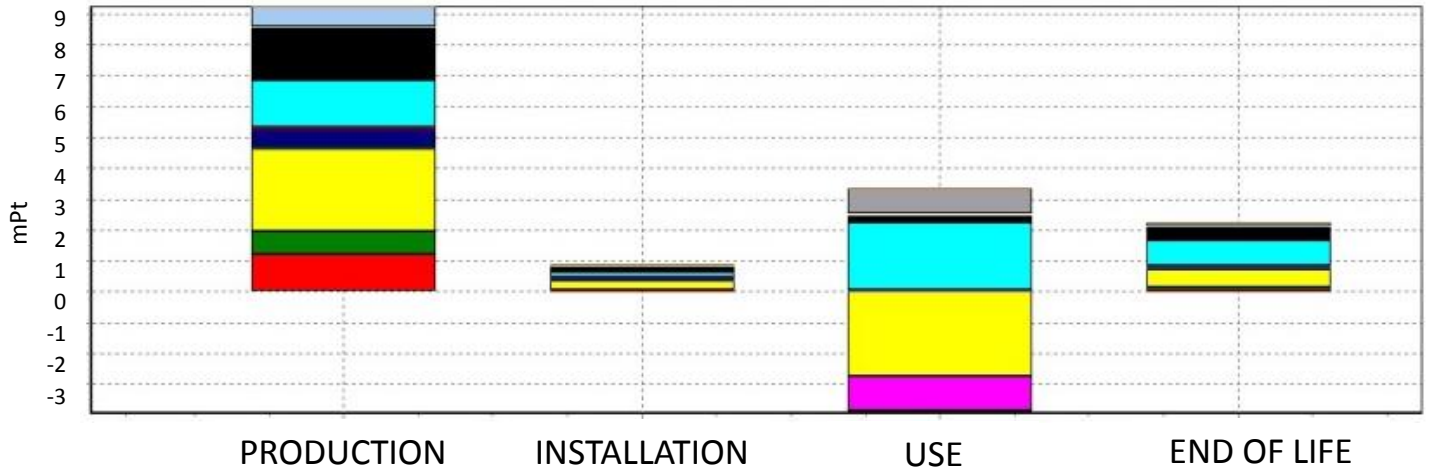
LCIA – Weighting



Most affected Impact categories	Amount (mPt)	Substance that produces the higher damage	Life cycle phase that produces the higher damage
Radioactive waste	0,87	Volume occupied	Production
Non-renewable energy	2,64	Oil crude in ground	Production
Global warming	4,65	Carbon dioxide fossil	Production
Respiratory inorganics	2,67	Particulates, <2,5 um	Production
Non carcinogens	0,65	Arsenic ion in water	Production
Carcinogens	1,28	Hydrocarbons, aromatic	Production
Carcinogens inhaled	0,829	Particulates, <100 nm	Use
Respiratory organics	-1,12	-Toluene in air	Use

Conclusions and reccomendations

- The **most impactful stages** of the life cycle of nanoTiO_2 glazed steel panel are: **production** of the steel panel and **application of white functionalized glaze**.
- This study is based on **assumptions** regarding the possible release of nanoparticles during the production stage but also during the use and end of life phases.
- All manufacturing processes are summarized conceiving the idea to **minimize all environmental loads**: the presence of **suction systems** and **personal protective equipment** to protect workers from dust and nanoparticles emissions were considered at all stages of the life cycle.
- The possible industrial scale-up has to **take into account all these precautionary systems** in order to manage the environmental burdens.
- It is still open the question of the **possible toxicity of nanoparticles**.

Thank you for your attention

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