



Multiple approaches for a complete mapping of nanomaterial uses: the case of nanosilver

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maîtriser le risque
pour un développement durable

Outline

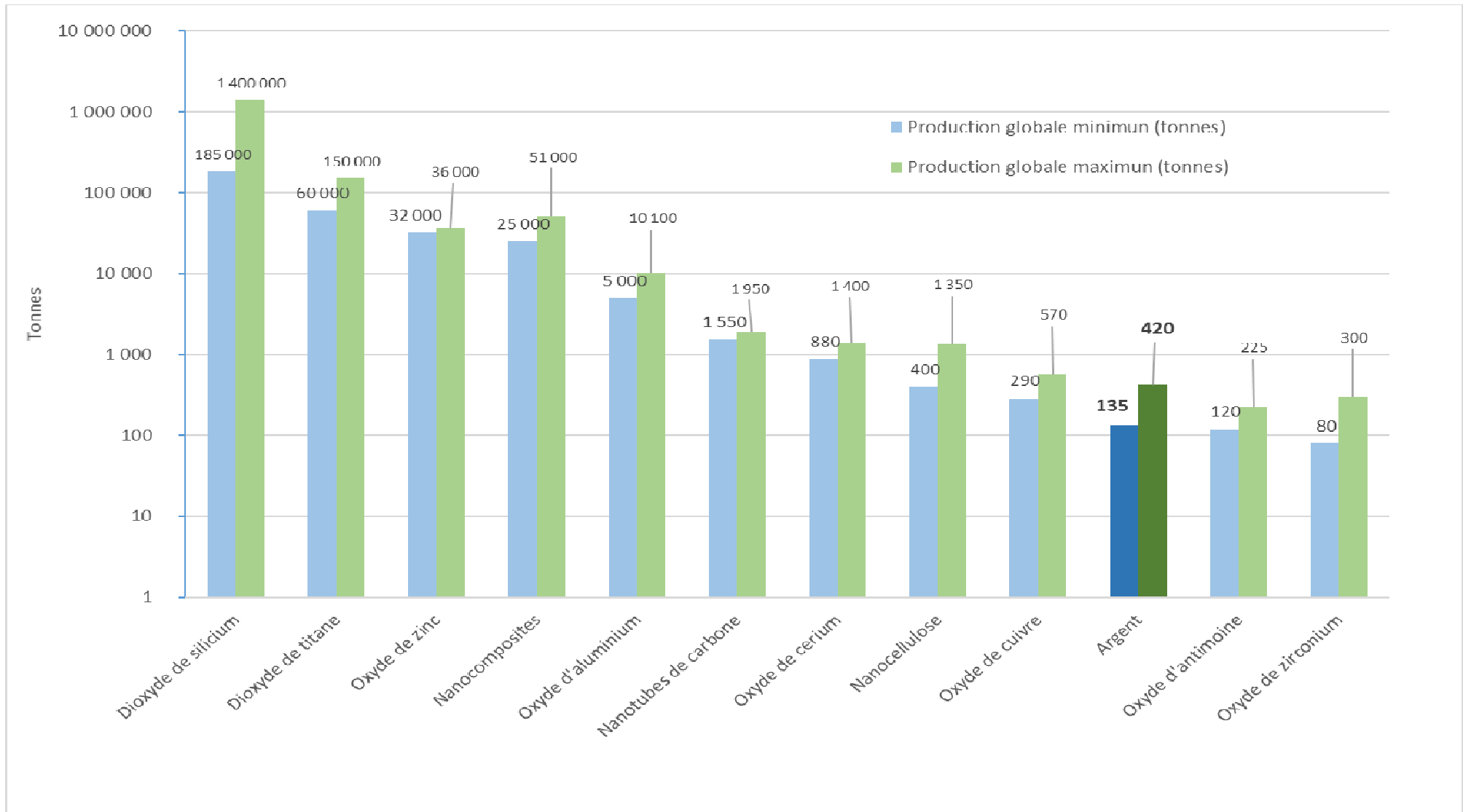
1. Objective of the study
2. Introduction : nanosilver market
3. Nanosilver inventories
4. Patent analysis
5. New approaches for mapping nanomaterial uses
6. Conclusions

1. Objective of the study

- To identify new profiles of industries beyond inventories.
- To give new points of view of suspected gaps between the number of registered end-products and consumer products on the market.
- To develop new approaches to map nanoparticle uses.
 - Study case of silver nanoparticle uses.

2. Introduction : nanosilver market

Global production of nanoparticles in 2015



Source: Pulit-Prociak et Banach, 2016.

2. Introduction : nanosilver market

Nanosilver production estimates :

References	Description	Nanosilver Production (tons/year)	Geographic Zone
NanoFATE	European Project 7FP	33.4	Europe
European Commission	Silver production for its antimicrobial properties in 2010	22	Global
Hendren, CO., et al. 2011	Production estimates for five nanomaterials: TiO ₂ , Ag, CeO ₂ , CNT, fullerenes	2.8 – 20	USA
Silver Nanotechnology Working Group (SNGW)	Silver Institute (international industry association)	250 - 312	Global
Nowack et al 2011	Study of the history of nanosilver	320	Global
Keller et al. 2013	Life cycle study of nanomaterial global emissions	≈400	Global

2. Introduction : nanosilver market

Nanosilver price estimates :

Companies	Size (nm)	Price (US\$/kg)
Blue Nano		
SLV-NW-90 Silver Nanowires	90±20 nm	4 950
SLV-NP-100 Silver Nanospheres	100±10 nm	3 490
NaBond Technologies Co., Ltd.	< 60	160
Inframat	50-80	179
SkySpring Nanomaterials, Inc	40	472
Sigma-Aldrich	< 50	3 200
Sun Innovations	25	18 000
Plasmachem GmbH	40	4 500

Source: [Pulit-Prociak et Banach, 2016], [Blue Nano, 2016], [silverprice.org], *company websites*.

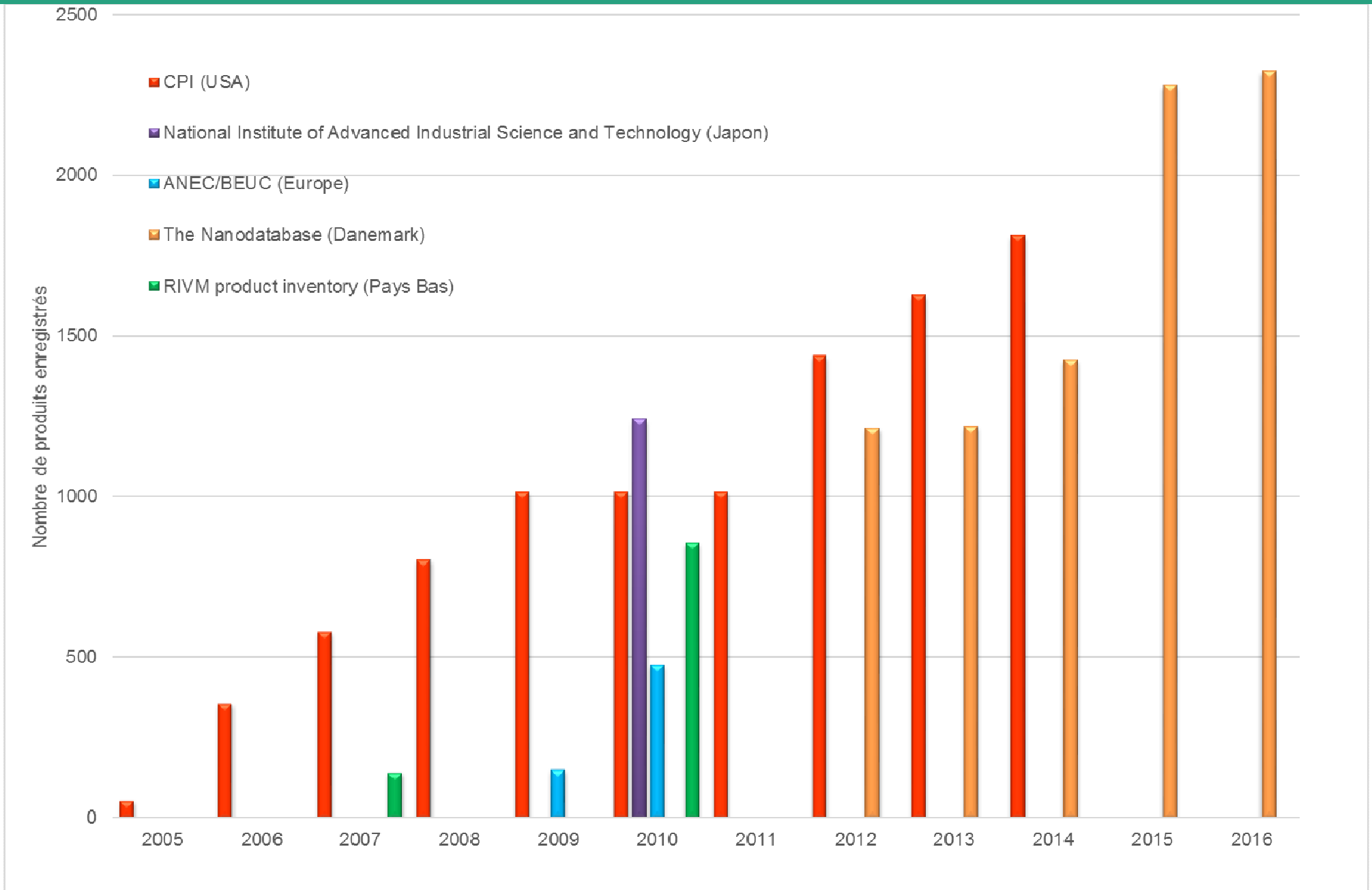
2. Introduction : nanosilver market

From applied research to commercialization:

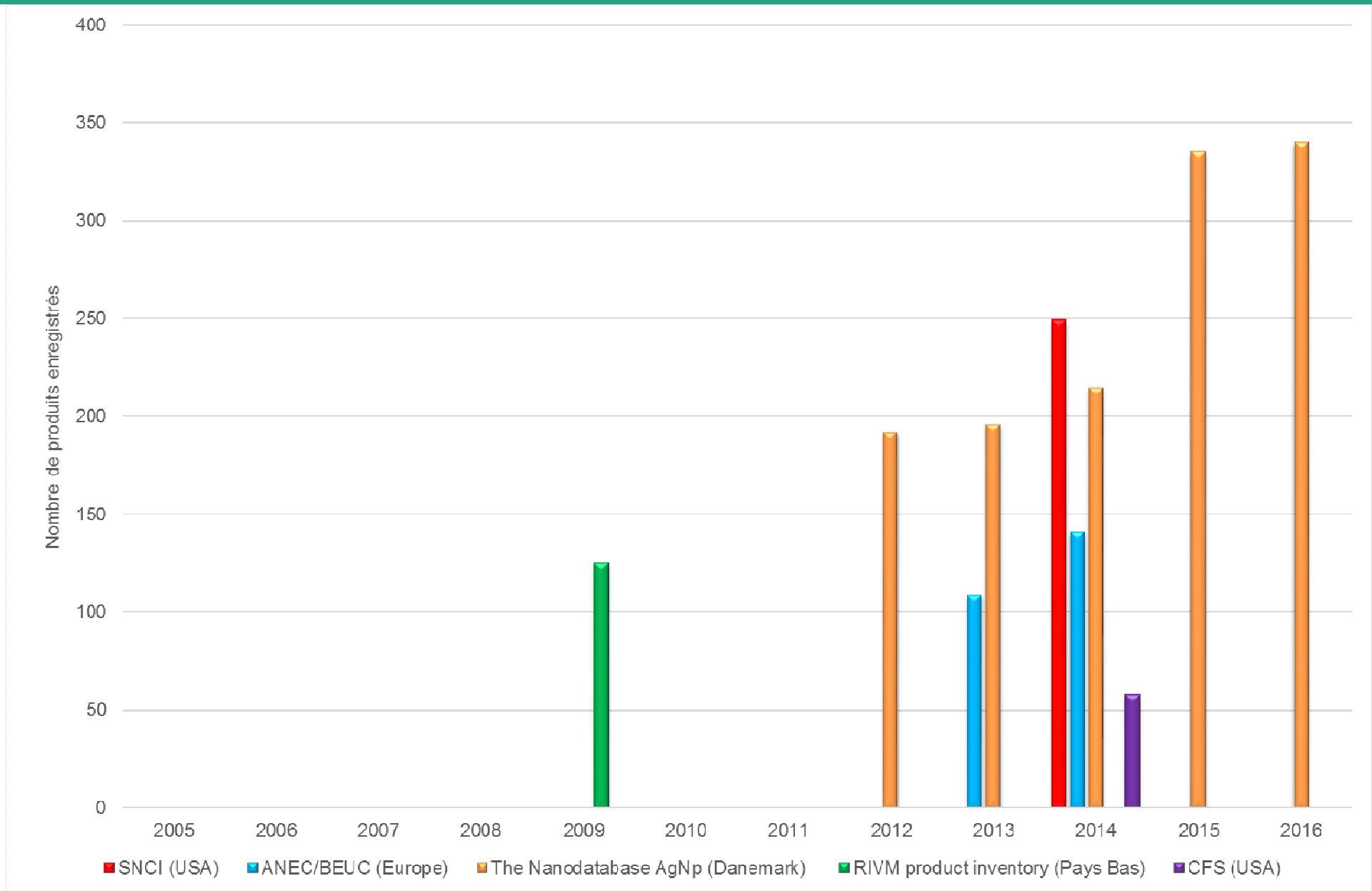
Applications	Applied research	Demonstration	Commercialization
Large volume			X
- Antimicrobial wound care			X
- Antimicrobial medical devices			X
- Antimicrobials in fabrics			X
- Water Purification		X	
- Conductive films and inks		X	X
Low volume			
- Food packaging		X	X
New applications			
- Intelligent glass (anti-reflect)	X		

Source: Pulit-Prociak et Banach, 2016.

3. Nanoparticle inventories (INERIS, 2016)

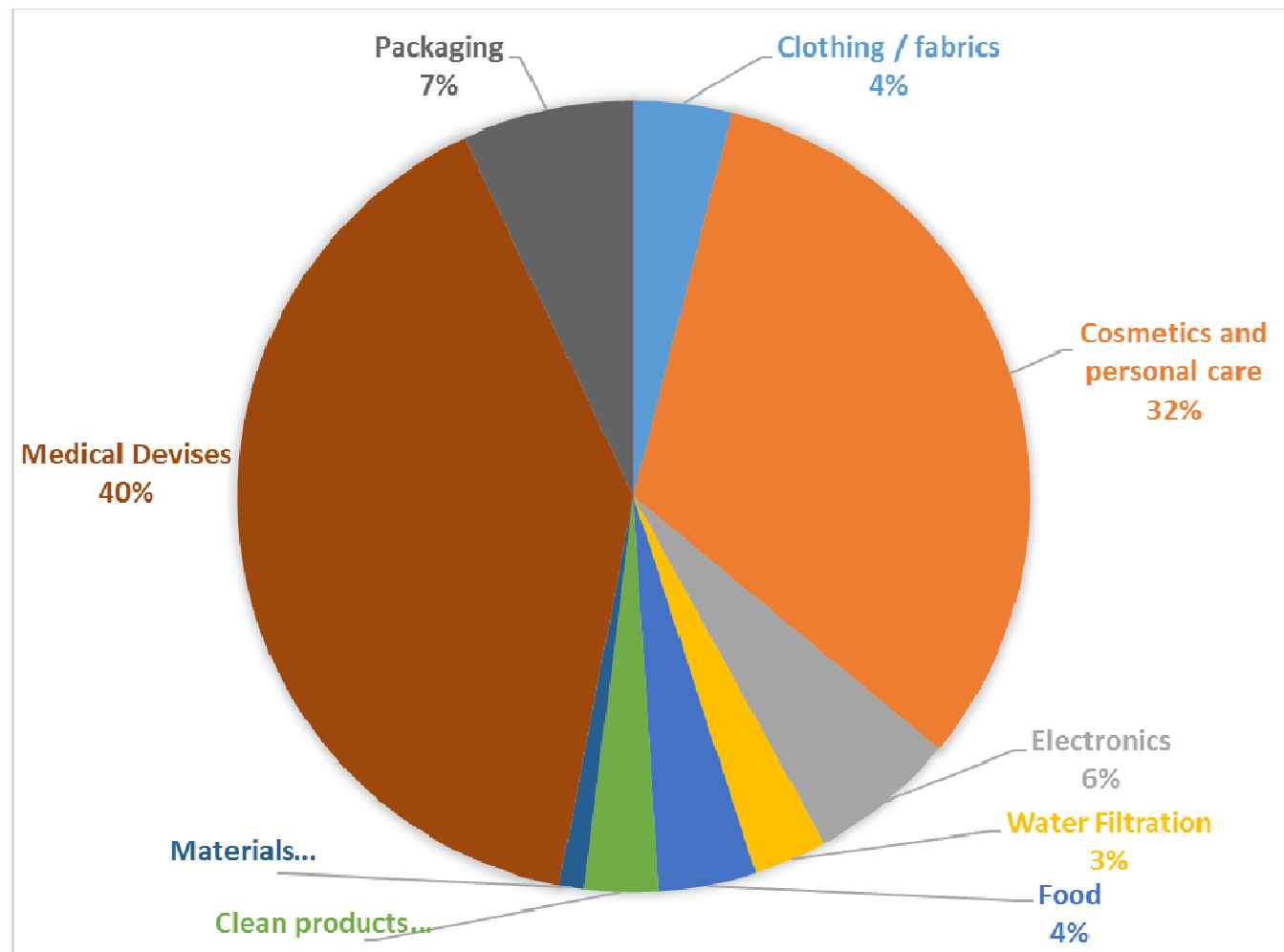


3. Nanosilver inventories (INERIS, 2016)



4. Patent analysis (Lem et al., 2012)

Distribution of the family patents involving silver nanoparticles from 1980 to 2010



4. Patent analysis (Lem et al., 2012)

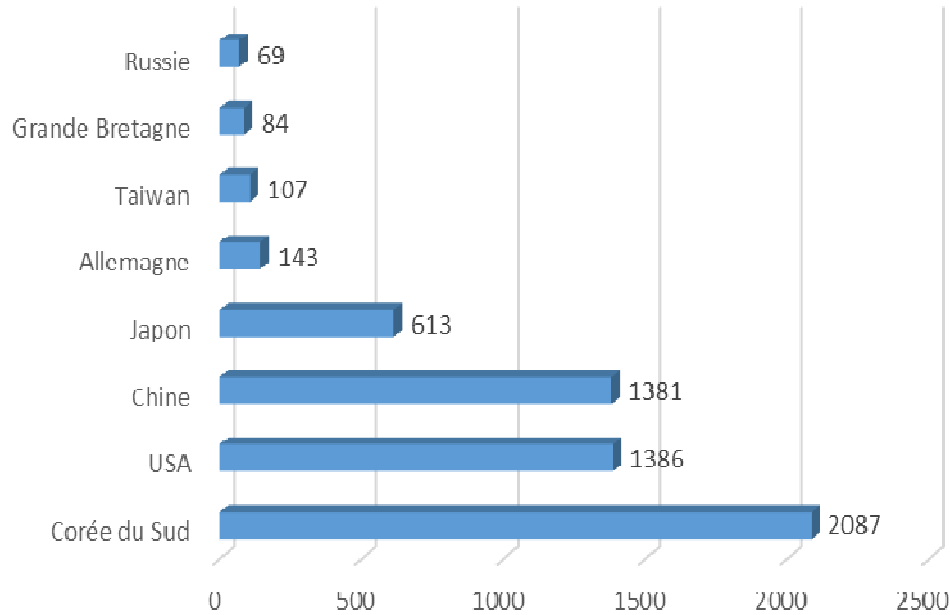


Fig1. Silver nanoparticle activity from 1980 to 2010. Source: Lem et al, 2016.

AgNp patent filling companies and universities from 1980 to 2010

Ag Np patent activity for consumer products.

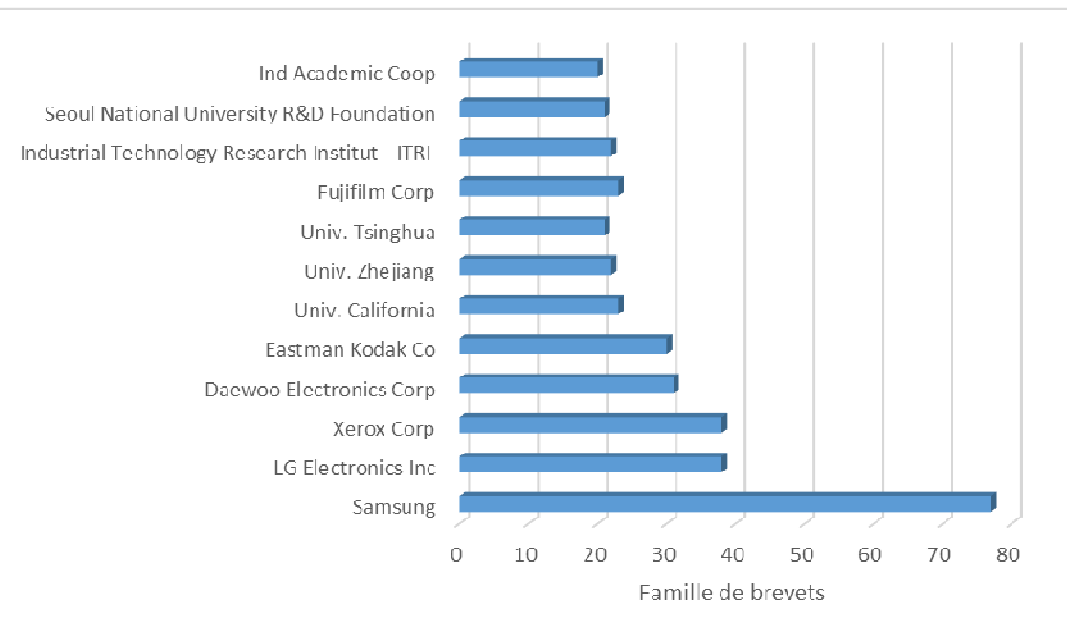


Fig2. Silver nanoparticle patent filling companies and universities from 1980 to 2010. Source: Lem et al, 2016.

4. Patent analysis (INERIS, 2016)

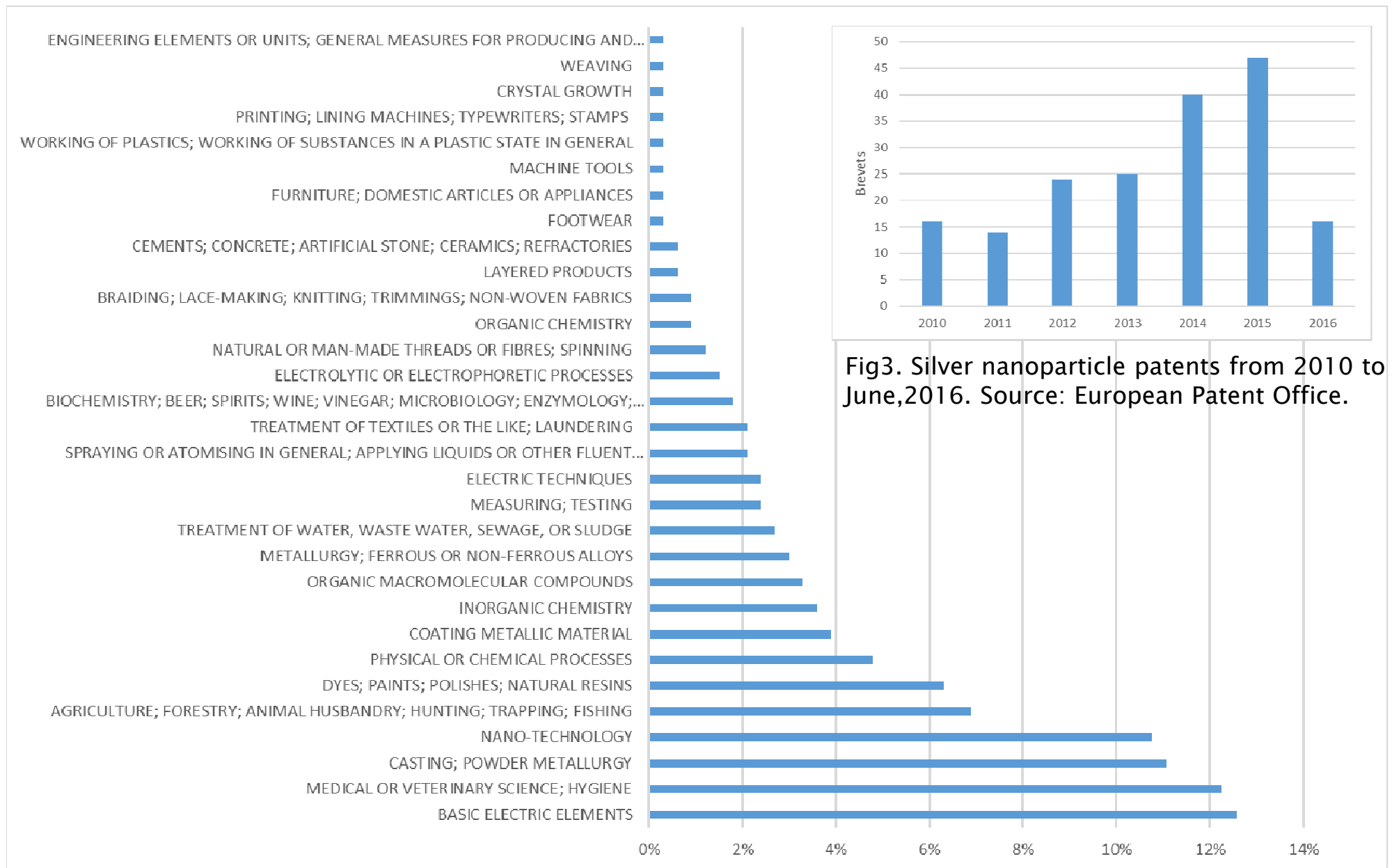


Fig4. Classification depending on CIB patent nomenclature from 2010 to June, 2016. Source: INERIS, 2016.

4. Nanosilver inventories and patent analysis

Nanosilver inventories and patents / Economic sector	SNCI (USA)	RIVM (Netherlands)	ANEC/BEUC (Europe)	Nanodatabase (Denmark)	Patents (1980-2010)
Health and fitness	54%			63%	
Medical applications	4%				40%
Electro-domestics	6%		33%		
Electronics	3%	23%		1%	6%
Cosmetics and personal care		24%	17%		32%
Fabrics and shoes/ clothes and textiles		27%	16%		Clothes/ Textiles : 4%
House and garden	11%		14%	14%	
Food and drinks	10%		1%	11%	4%
Water filtration					3%
Packaging					7%
Materials					1%
Public uses	2%				
Children products	2%		11%	5%	
Automobile			2%	1%	
Furniture and clean products		15%			3%
Filtration, purification		10%			
Divers products (transversal)			6%		

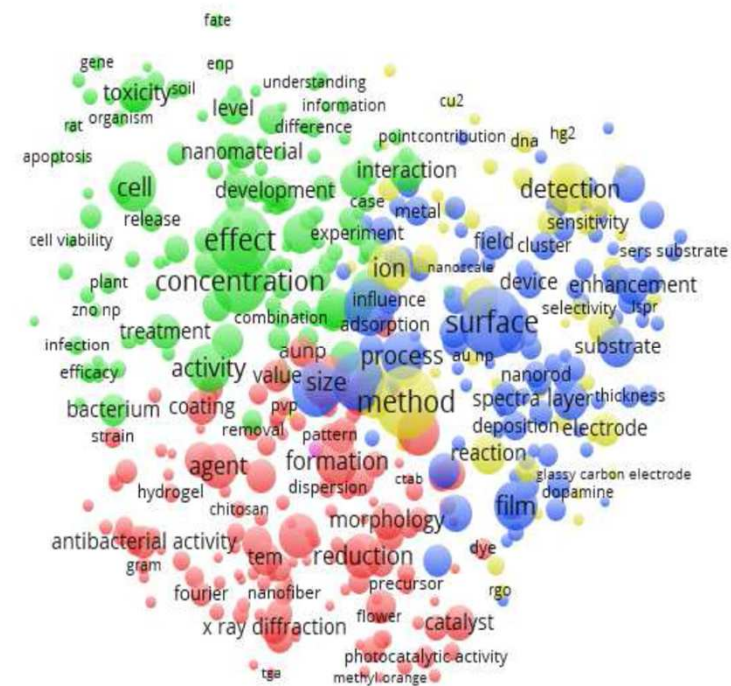
5. Framework of alternative approaches

1. Data collection
(*Web of Science*)

2. Grouping the keywords
(*clustering*)

3. Interpretation of clusters
(analysis of experts)

4. Mapping the categories
identified



5. New approaches for mapping nanomaterial uses

Data collection:

■ Bibliometric analysis:

- Database: Web of Science Core Collection (41,278 citations)
- Keywords: silver nanoparticle and nanosilver
- Between 1992 and 2016.

■ International press analysis:

- 446 newspaper articles listed in the database Nexis.
- We evaluated the occurrence on each category of inventory CPI.
- Keyword "nanosilver".

5.1. Bibliometric analysis (INERIS, 2016)

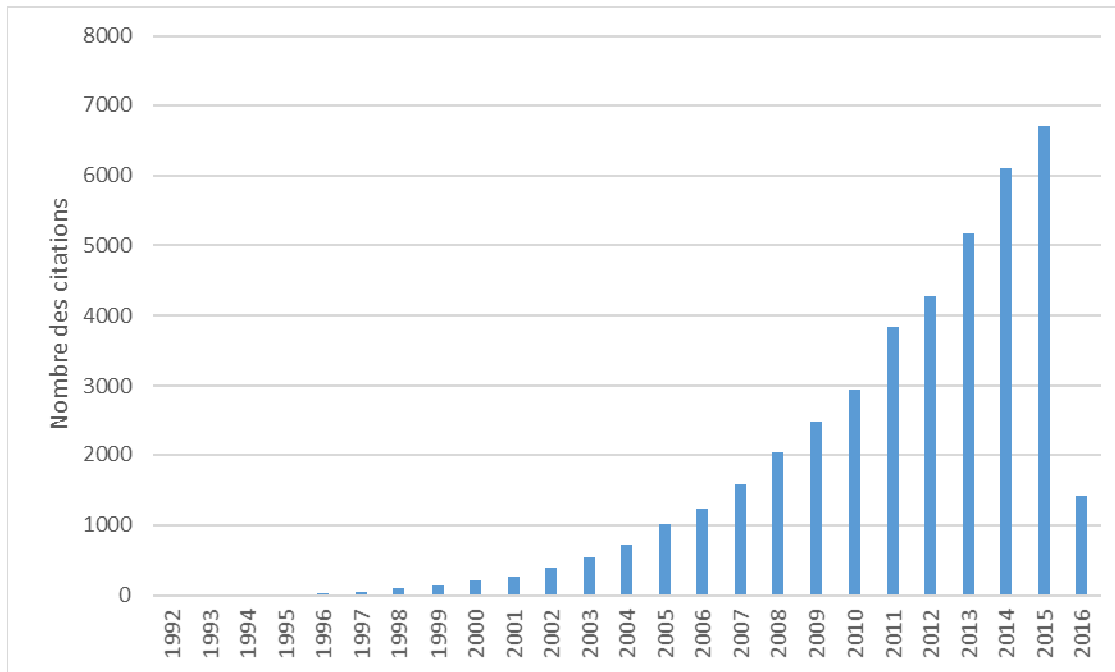


Fig5. Research citations of silver nanoparticles from 1992 to June, 2016. Source: INERIS, 2016.

Authors are mainly associated with universities or research centers

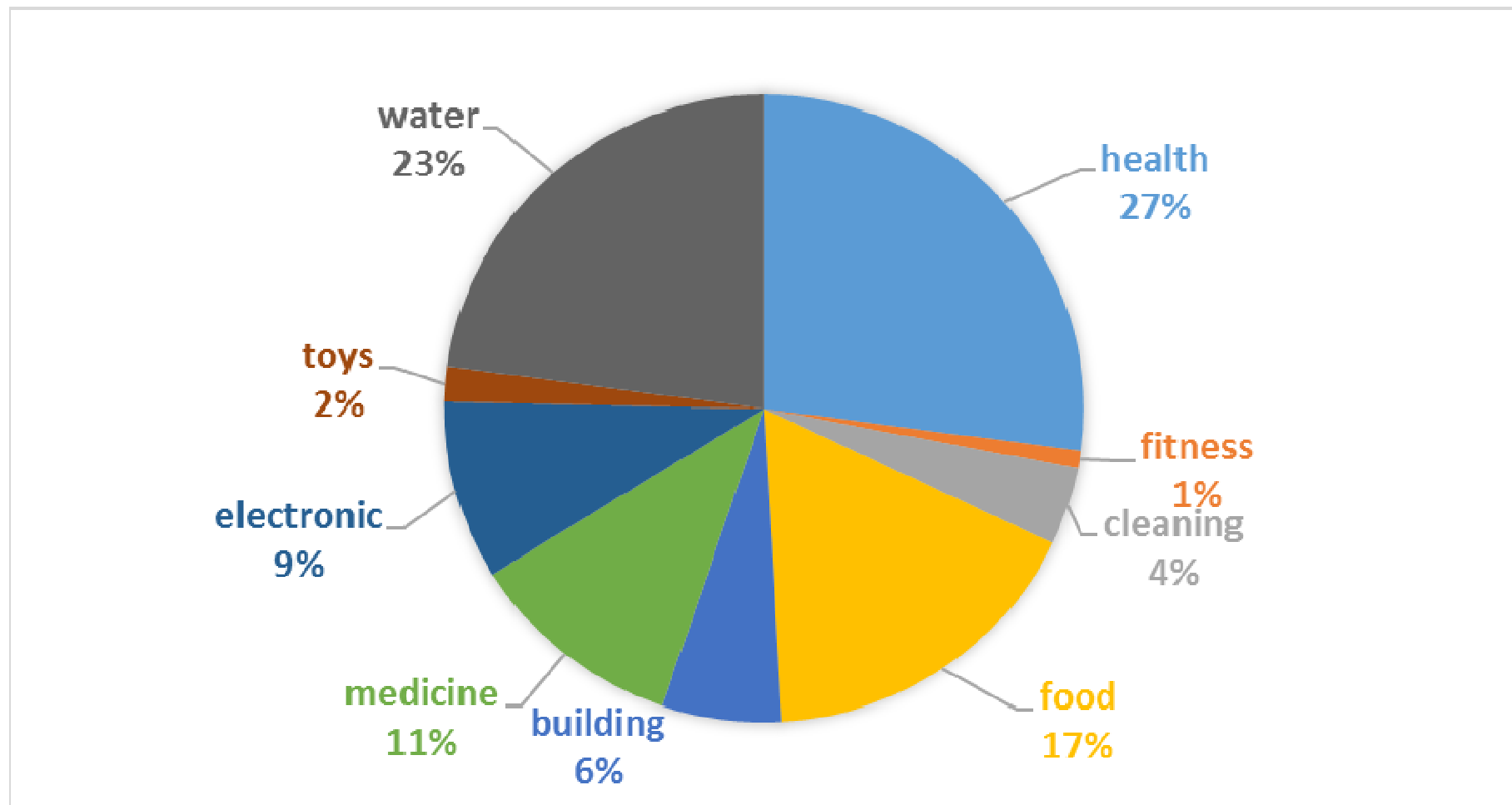
Region/ Countries	% / 41 278 citations
Asia	48,2 %
China	24,9 %
India	11,4 %
South Korea	6,7 %
Japan	5,1 %
Europe	21,4 %
Germany	5,0 %
France	3,5 %
Italy	2,8 %
Spain	2,7 %
England	2,7 %
Poland	1,7 %
Swiss	1,1 %
Romania	1,0 %
Czech Republic	0,9 %
USA	17,8 %
Iran	3,4 %
Taiwan	3,1 %
Russia	2,6 %
Canada	2,2 %
Australia	1,8 %
Singapore	1,6 %
Brazil	1,5 %
Saudi Arabia	1,3 %
Mexico	1,2 %
Malaysia	1,1 %
Egypt	1,0 %

5.1. Bibliometric analysis (INERIS, 2016)

Categories	Number of keywords	Exemples of keywords
Potential nanoparticle applications	91	catalyst, coating, cotton fabric, drug, glass, food, energy, ascorbic acid (produits liés aux catalyseurs), biofilm, biomolécule, ag-cysteine (usage dans les hydrogels).
Characterisation tools	58	atomic force microscopy, energy dispersive x ray spectroscopy, plasmon resonance, thermogravimetric analysis.
Nanosilver characteristics	31	antibacterial activity, antimicrobial activity, average size, conductivity, diameter, optical property, area, surface morphology.
Toxicology and écotoxicology	28	cancer cell, cell viability, cytotoxicity, reactive oxygen species, vitro.
Without identification	9	Biocompatibility, deposition, green synthesis, incorporation.
General keywords	225	consumer product, concentration, measurement, parameter, performance
Total keywords analysed	442	

5.2. International press analysis (INERIS, 2016)

Distribution of the CPI categories and nanosilver in the public sphere (international revues, journals, web)



6. Conclusions

- Today, consumer product inventories claiming Np/AgNp are the main data sources; however, there is a gap between inventories and the consumer products on market claiming Np.
- Heterogeneity of the data collected and collection methods make difficult the comparisons between nanoparticle inventories.
- Integrating patent analysis seems the best approach to explore future end-uses and indentify technological process.
 - Exemple: water filtration (category misidentified in the inventories).

6. Conclusions: Alternative methods

■ Bibliometric analysis

- Increase of research on nanosilver : dominant position of Asia in scientific production comparing to EU countries.
- Bibliometric approach identifies potential applications by clustering relevant keywords.
- Next step: to review scientific articles following relevant keywords identified.

■ International press analysis

- Press review shows a vision of the end-uses in the public sphere (reviews, journals, magazines, web articles).
- We note that specific categories related to health, water and food are more represented in the public sphere than in the inventories.

EDEN – Economics and Decision for the Environment

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