SKEP ERA-net
Scientific Knowledge for Environmental Protection

Work Package 6 – Investigate emerging issues for future research planning

Deliverable 6.3

Nano-Bio-Info-Cogno technologies and the environment

Summary of perceptions and science needs of policy makers, operational staff, scientists, experts and stakeholders

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SIXTH FRAMEWORK PROGRAMME

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INTRODUCTION

The WP6 SKEP questionnaire was available online from the third of December 2007 to the sixth of January 2008[1]. An invitation email was sent to 748 persons identified through a literature review and by the European network SKEP, as experts in the field of nanotechnology, biotechnology, IT or cognitive sciences. In order to increase the number of responders, an external link to the questionnaire was also provided. . 157 responders answered the questionnaire. 136 of them were directly invited, 21 used the external link. The answering rate is 18,2% *stricto sensu* or 20,1% all in all.

157 responses mean that one should be cautious with the statistical significance of the results presented here. Only general trends and major discrepancies among distinct groups (around 20%) can be considered as truly significant.

The questionnaire consists in 4 parts:

- The first one concentrates on the environmental and health impacts of converging technologies in general. The aim of this part is to enlighten perceptions and science needs concerning environmental and human health impacts of convergent technologies (CTs) in general
- The second part is dedicated to a risks/benefits evaluation of a panel of CTs environmental applications. In this part, responders were asked to assess the priority of public support to R&D activities allowing the full development of the most promising technologies.
- The third part focuses on the needs and opportunities for public regulation of converging technologies in general. Special attention is paid to scientific knowledge and technical basis needed to implement regulatory measures.
- The fourth part is based on two open questions focusing on the top priorities for public authorities in terms of regulatory action and scientific research.

In this questionnaire, responders can use the answer "unknown" if they think that the current scientific knowledge available is clearly insufficient to answer the question. When they believe that they lack expertise to answer the question or if they do not want to answer, they are kindly asked to use the "no answer" option. This distinction has been made in order to focus on scientific knowledge gaps that challenge action from public authorities.

The SKEP WP6 questionnaire is an input to a European workshop in Paris on the 28-29 February 2008. This workshop will gather more than 50 participants, mostly public and operational staff but also scientists, industrials and NGO representatives. The aim of the workshop are to feed back the results of the literature reviews and the questionnaire to SKEP members and stakeholders, to complete this material with

[1] This consultation has been conducted in compliance with European regulation on personal data protection. Personal data have been collected and processed only for statistical purposes. If responders want to have access to their personal data collected by this survey, they are welcome to write to cnil@ademe.fr

presentations and working groups involving experts, policy makers and stakeholders, and to make recommendations for future research. The final report of WP6 is one of the main drivers for the third and main joint call for research of SKEP in 2009.

THE PANEL OF RESPONDERS

Responders are asked to provide personal information in order to better evaluate how representative the panel of respondents were. This information also allows us to search for major discrepancies between distinct groups.

Kind of opinion

To begin with, responders are asked to declare if their answers reflect their personal opinion or the general opinion of their organization/institution.

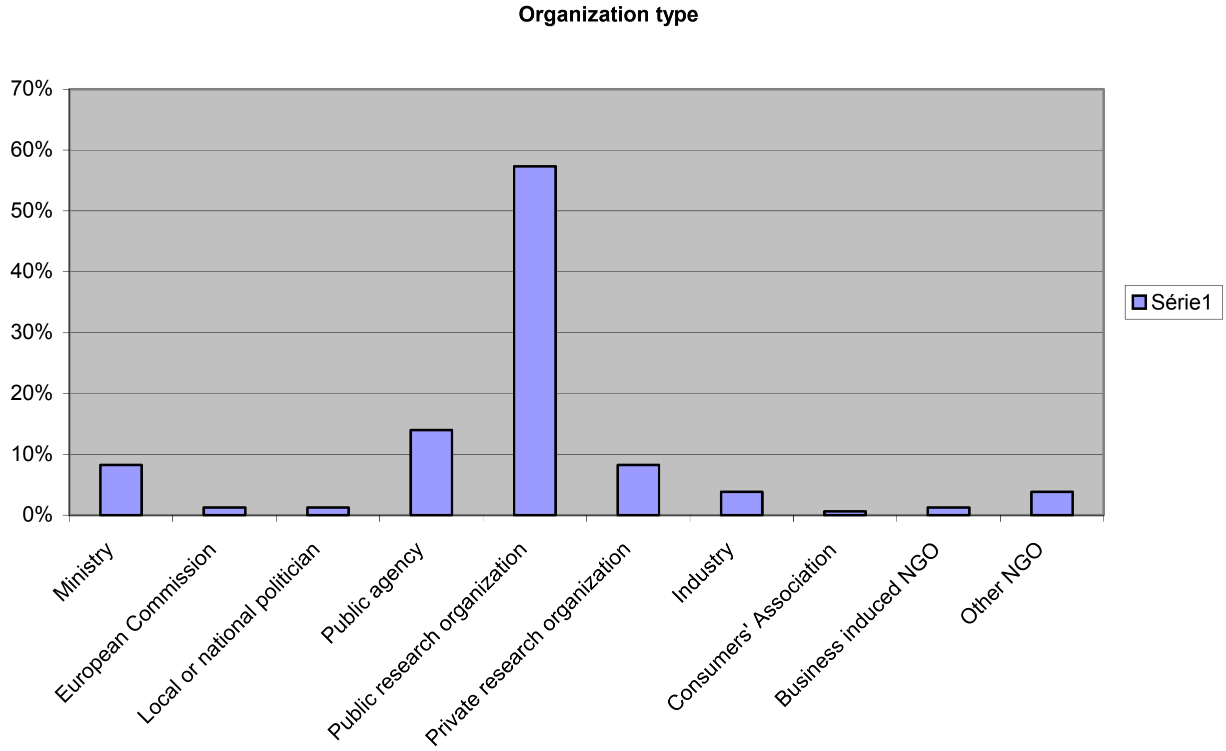
Kind of opinion		
	All	**NGOs**
Your personal opinion	92,4%	66,7%
The general opinion of your organization/institution	7,6%	33,3%

The kind of opinion declared is, for **92,4%, the personal opinion** of the respondent. As a consequence, the results of this questionnaire reflect the opinion and perceptions of individuals having positions within organizations and institutions and not the official views of these organizations and institutions. One can explain this result in two different ways:

- organisations have not yet decided a common position on the rather new subject of environmental impacts of NBIC convergence
- individuals do not have the legitimacy, clearance or authorisation to answer on behalf of their organisation

NGOs are an exception, with one third of the responders answering in line with the general opinion of their organisation. This could mean that NGOs, in comparison with other kind of actors, are more advanced or less rigorous in building a collective position on NBIC convergence.

Organization type



In this study, we will consider:

- «Ministry», «Public agency», «European Commission» «Public research organization and universities» as «**public sector**».
- «Industry», «Private research organization» and Business induced NGO as «**private sector**».
- «Local or national politician» , «Consumers' Association» and «Other NGO» as «**civil society**»

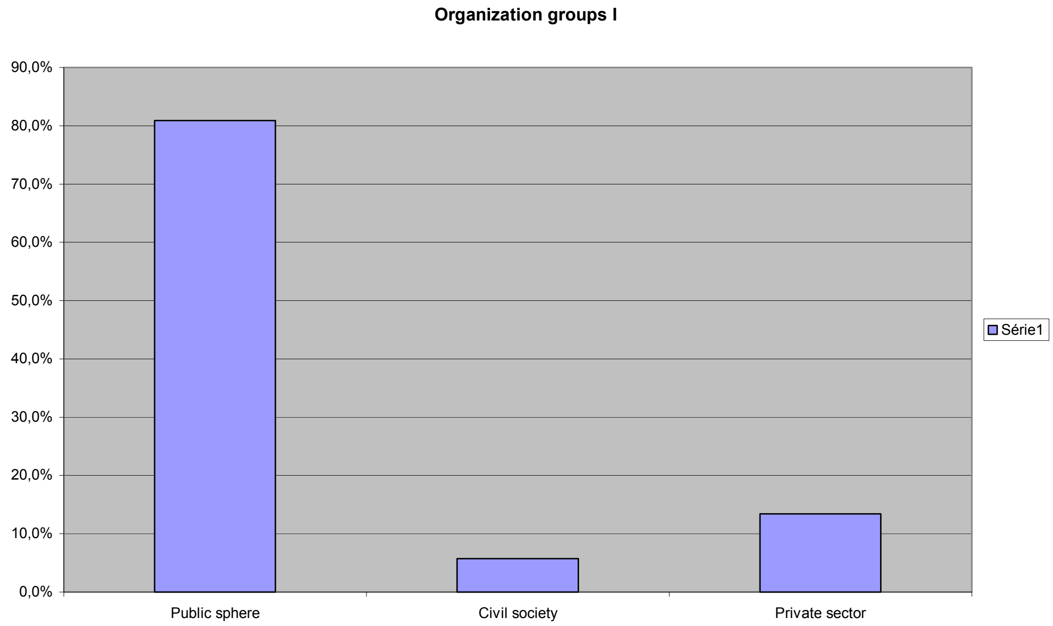
We will also consider:

«Public research organization and universities» and «Private research organization» as «**scientific community"**»

«Ministry», «Public agency», «European Commission», «Industry», «Business induced NGO», «Local or national politician» , «Consumers' Association» and «Other NGO» as «**non scientists**».

Organization type	
Ministry	8,3%

European Commission	1,3%
Local or national politician	1,3%
Public agency	14,0%
Public research organization	57,3%
Private research organization	8,3%
Industry	3,8%
Consumers' Association	0,6%
Business induced NGO	1,3%
Other NGO	3,8%



These first groups are very unequally distributed with a big majority of "public sector" responders in comparison with the very small "civil society" group. Therefore, one should be cautious with the statistical significance of discrepancies between these groups. Only mean deviations of 20% or higher are statistically significant.

65.6% of the responders belong to the scientific community. This majority of scientists can have affected the result of the questionnaire. The inclination to consider the necessity of public research can be higher among scientists, due to their direct interest in the matter. As scientists and due to the proximity to potential risks of some of those working on CTs, their inclination in considering high levels of risks can also be smaller.

Academic background

In this study, the various responders' academic backgrounds have been grouped in 4 categories:

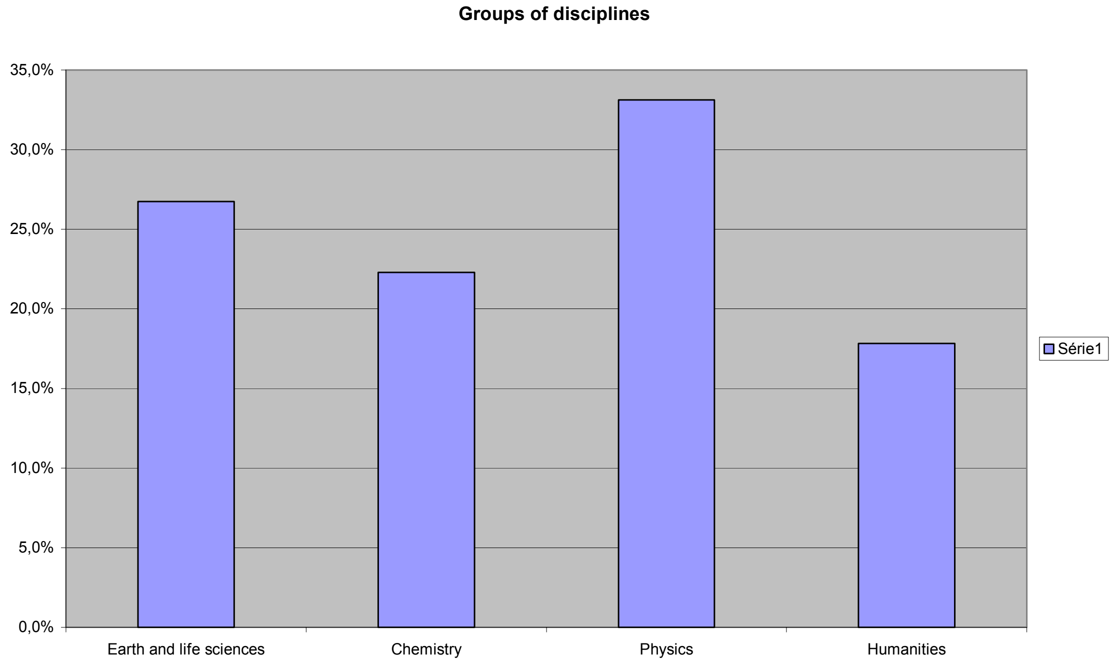
Humanities: economics, management, law, political sciences, philosophy, history, sociology, science and technologies studies (STS), cognitive sciences, communication sciences.

Earth and life sciences : biology, medicine, pharmacy, toxicology, environmental sciences, life sciences, nature sciences, agronomics, oceanography, geology.

Chemistry : chemistry.

Physics: material sciences, mechanical engineering, mathematics, physics, computing, electronics.

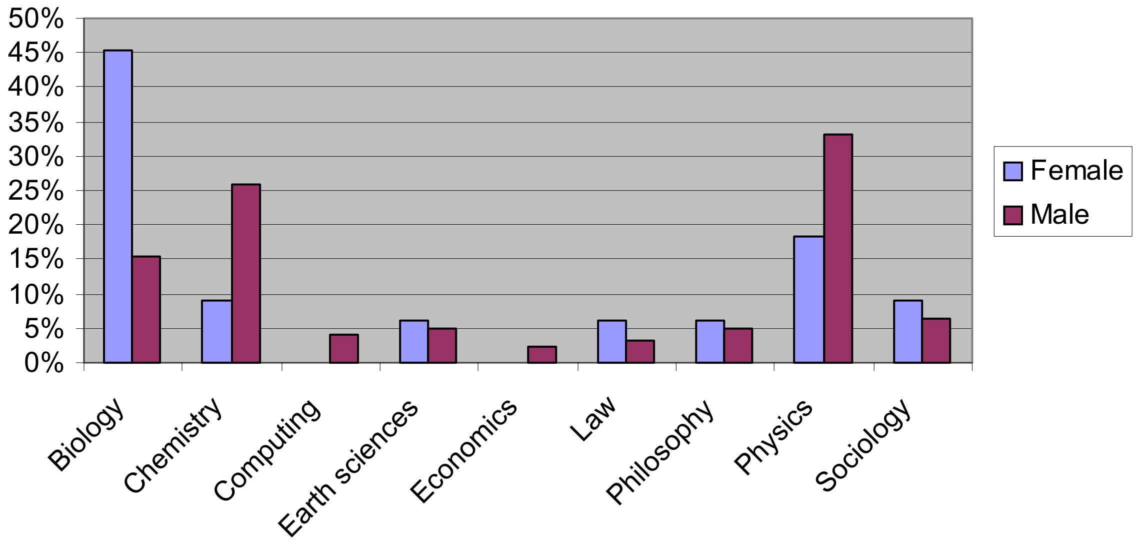
Academic background			
Biology (incl. medicine, pharmacy, toxicology)	21,7%	**Earth and life sciences**	26,8%
Earth sciences (incl. environmental sciences, life sciences, nature sciences, agronomics, oceanography, geology)	5,1%		
Chemistry	22,3%	**Chemistry**	22,3%
Computing (electronics)	3,2%	**Physics**	33,1%
Physics (material sciences, mechanical engineering, mathematics)	29,9%		
Law (political sciences)	3,8%	**Humanities**	17,8%
Philosophy (history)	5,1%		
Economics (management)	1,9%		
Sociology (STS, cognitive sciences, information and communication sciences)	7,0%		



Gender

Gender	
Male	79%
Female	21%

With 79% of the responders, men are clearly over represented. This can have consequences for the results of this questionnaire. In fact, opinion surveys have shown that women present a greater sensitivity to risk. The under-representation of women here could lead to an underestimation of potential risks.



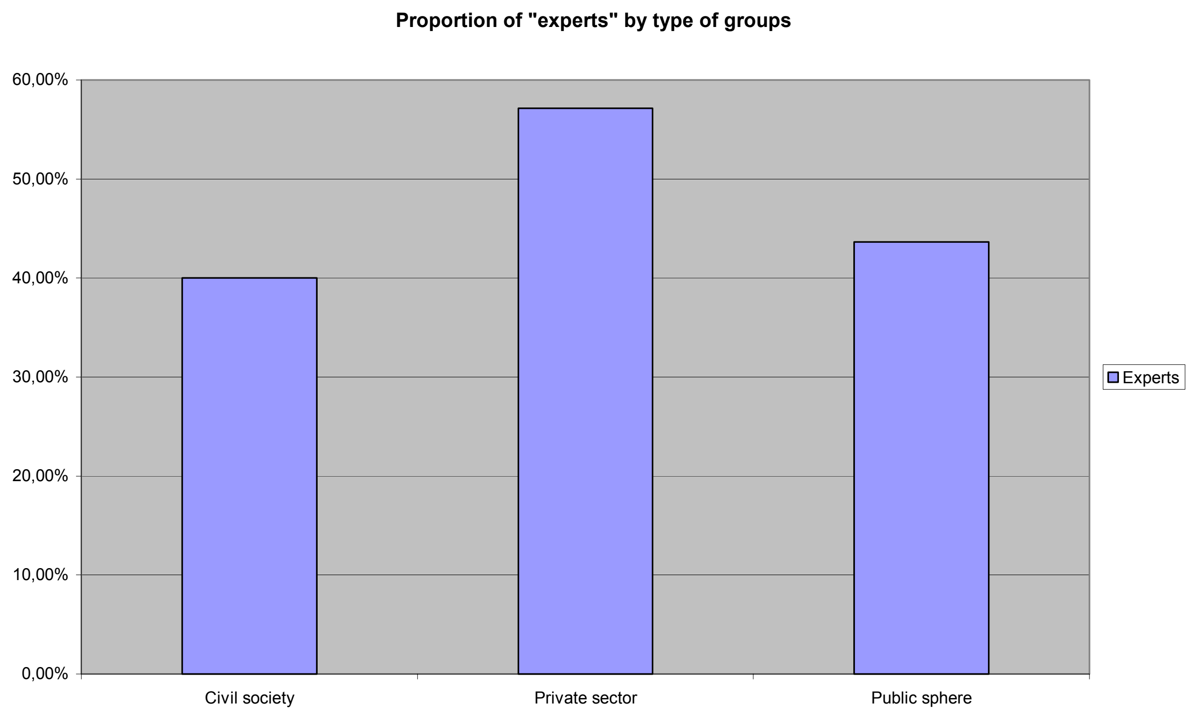
The gender and academic background distribution is rather classical. Women are in majority in humanities, except economics biology and earth sciences. Therefore, any academic background bias could be in fact a gender effect and *vice versa*. The panel of responders is not large enough to statistically discriminate these two effects.

Self evaluation of knowledge:

The panel of responders is more expert in nanotechnology than biotechnology, IT or cognitive sciences. This result is consistent with the academic background distribution.

Self evaluation of knowledge			
	Nanotechnology	**Biotechnology**	**IT and cognitive sciences**
Novice	18,5 %	45,9%	57,3%
Competent	47,8 %	41,4%	36,3%
Expert	33,8 %	12,7%	6,4%

In this study, we consider as «expert» any responder that has declared to be an expert in at least one of the three areas. This will allow comparisons between experts and non experts.



It is interesting to note that a higher proportion of private sector responders consider themselves as expert in at least one of the three areas. The low level of expertise in the public sector may be see as hampering the capacity of public authorities to efficiently regulate CTs development.

Country

More that 1/3 of responders are French and 1/4 Austrian. Other responders are from Belgium, Finland, Germany, Italy, Netherlands, Norway, Poland, United Kingdom, Mexico and the United States.

Euro barometers have shown that Austria is an exception within Europe concerning attitudes towards science and technologies. Austrians appear to be more sceptical and less confident in comparison with other European countries. On the contrary, France appear as a rather "scienticist" country. One could then assume that, in terms of risk and benefit perceptions, the two effects would tend to balance one another.

1/ Potential risks of converging technologies and public research needs

This part of the questionnaire is organised around five groups of application of converging technologies (free standing nanoparticules, embedded nanoparticles, nanostructured materials, elec/opto/mecatronic nanodevices and nano-bio devices).

The aim of this part is to rank these technological applications with regard to:

- the perceptions of sanitary risks
- the perceptions of environmental risks
- the perception of irreversibility in case of realized risk
- the priority of public research on these topics
- the perception of social acceptance
- the need for actions targeted to the citizen

Then, the priority of research funding is derived from all these rankings.

In the following tables, the most frequent answers are highlighted in red (first), yellow (second) and the less frequent answers in green.

1.1 Human health (sanitary risks)

Chart 1.1: Human health

	Free standing nanoparticules	Embedded nanoparticles	Nanostructured materials	Elec/opto/meca nanodevices	Nano-bio devices
Very low+ low	19,8%	55,8%	56,7%	71,4%	46,1%
High+very high	43,3%	21,2%	21,6%	8,9%	23,1%
Unknown	34,4%	21,8%	17,2%	12,7% (Na:7%)	20,5% (Na:10,3%)
Priority of public research (high+very high)	84,7%	67,9%	59,9%	33,2% (Na: 8,3%)	49,4% (Na: 12,2%)

Concerning human health issues, free standing nanoparticles are considered as potentially more harmful than nanostructured material and embedded particles. The uncertainties ("unknown") concerning sanitary risks are also the highest (34,4%). Note that nano-bio devices are also perceived as potentially harmful in a large proportion (23,1%) with a high rate of "unknown" answers (20,5%).

Logically, responders consider that public research on human health risks should focus on free standing nanoparticles. More surprisingly, they also consider that embedded nanoparticles and nanostructured materials are the second and third priorities for public research. This could be related to a rather high level of risks (more than 21% of high and very high) and of "unknown" answers (21,8% and 17,2%). This could also reflect the fact that if studies on these applications have shown a lower degree of sanitary risks so far, they are still rare and should be completed.

As shown in green, the lowest rate of perceived sanitary risk, lowest rate of "unknown", lowest priority for public research, and elec/opto/mecatronic nanodevices represent an exception. In fact, electromagnetic pollution is not established yet or debated. This point of view is shared by 71,4% of responders. Though, for this particular kind of application, responders could quote a "personal data protection risk". When looking at this specific item, 63,1% of responders consider that the risk is high or very high, with a very low level of uncertainty (only 7% of unknown). Risks for humans are not sanitary but socio-political. From this point of view, elec/opto/mecatronic nanodevices appear to be the most risky kind of applications. Still, this is not a clear priority for public research, as uncertainties are very low and as the "solution" might be more political regulation than scientific and technical improvements.

Chart 1.2: Elec/opto/meca nanodevices and personal data protection risk	
Very low+ low	21%
High+very high	63,1%
Unknown	7% (Na: 8,9%)
Priority of public research (high+very high)	47,8%

1.2 Environmental risks

Opinion surveys have shown that, most of the time, human heath risks are better known and a greater concern than environmental risks. In this questionnaire, this is the case concerning free standing nanoparticles and nano-bio devices. On the contrary, embedded nanoparticles, nanostructured material, elec/ opto/ mecatronic nanodevices present a higher level of perceived environmental risks than human heath risks. One can also note that the discrepancies between the level of risk between free standing and embedded nanoparticles is lower for environmental risks (32,5% and 30,8%) than for human heath risks (43,3% and 21,2%).

Chart 1.3: Environmental risks	Free standing nanoparticules	Embedded nanoparticles	Nanostructured materials	Elec/opto/meca nanodevices	Nano-bio devices
Very low+ low	26,7%	43,6%	49,1%	58,6%	48,8%
High+very high	32,5%	30,8%	27,4%	16,5%	17,9%
Unknown	40,1%	23,7%	20,4%	18,5% (Na:6,4%)	22,4%
Priority of public research (high+very high)	78,3%	65,4%	57,7%	36,9% (Na:8,3%)	39,7% (Na:12,8%)

Opinion surveys have shown that, most of the time, human heath risks are better known and of greater concern than environmental risks. In this questionnaire, this is the case concerning free standing nanoparticles and nano-bio devices. On the contrary, embedded nanoparticles, nanostructured material, elec/ opto/ mecatronic nanodevices present a higher level of perceived environmental risk than human heath risks.

1.3 Irreversibility in case of realized risk

Chart 1.4: Irreversibility in case of realized risk	Free standing nanoparticules	Embedded nanoparticles	Nanostructured materials	Elec/opto/meca nanodevices	Nano-bio devices
Very low+ low	19,9%	30,8%	36,2%	34,6%	33,1%
High+very high	41,1%	30,2%	25,7%	28,2%	25,3%
Unknown	32,7 % (NA: 6,4%)	30,8% (Na:8,3%)	27,6% (Na:10,5%)	25% (Na: 12,2%)	26% (Na: 15,6%)

Here, responders were asked to assess the level of irreversibility in case of realized risk. What is at stake is the ability to remediate incidents or pollution. The issue is not only about the level of potential damage but about how long these damages will last, which is a legacy to future generations. One can observe that the ranking between different kinds of applications does not change in comparison with environmental and human heath risks. What is changing is the level of "high and very high" answers, which is higher (free standing nanoparticles, electro: opto/ mecatronic nanodevices) or similar (embedded nanoparticles, nanostructured material) in comparison with environmental risk and human heath risks. This means that responders consider irreversibility as a significant concern regarding the development of CTs. This could give ground for implementation of the precautionary principle.

Except for free standing nanoparticles, the level of "unknown" is always higher for irreversibility. This result is logical as this risk is more difficult to investigate.

1.4 Social acceptance

Chart 1.5: Social acceptance

	Free standing nanoparticules	Embedded nanoparticles	Nanostructured materials	Elec/opto/mecatronic nanodevices	Nano-bio devices
Very low+ low	44,6%	24,2%	24,4%	40,1%	54,5%
High+very high	43,9%	61,6%	59,6%	45,9%	25,7%
No answer	11,5%	14,1%	16%	14%	19,9%

To begin with, social acceptance appears as a clear concern for ¼ to ½ of the responders, who consider that the social acceptance of all the 5 kind of CTs applications is low or very low. Looking at the different kind of applications, social acceptance seems to be related to risk perception. It is considered higher for embedded nanoparticles and nanostructured materials than for free standing nanoparticles. Although, the lowest rate of social acceptance is for nano-bio devices, which are not considered as presenting the highest level of risk. This result illustrates that social acceptance is not only about perceived risks but may also depend on representations and symbols. Biotechnologies through GMOs have already raised opposition from the public in some countries and manipulation of living materials is controversial. Moreover nano-bio applications question the frontier between living and non living material.

Between 11,5% and 19,9% of the responders have chosen "no answer. This result could be interpreted in two different ways. On the one hand, the high proportion of "no answer" may be linked to the main academic background of the responders. Indeed, with only 17,8 % of responders with a background in humanities, the panel may lack expertise to assess the social acceptance of CTs. note that, most of the time, there is less than 5% of "no answer" quoted when the "unknown" option is possible (exceptions are indicated). On the other hand, the "unknown" option was not available for social acceptance[2], so the high level of no answer could also mean a lack of scientific knowledge concerning social acceptance. Public research should consequently help fill the gap on this topic.

[2] By not proposing « unknown » concerning social acceptance, authors wanted to capture perceptions of responders, assuming that everybody, embedded in society, might have an idea concerning this issue.

1.5 Need for specific actions targeted to the citizens

Chart 1.5 Need of specific actions targeted to the citizens	Free standind nanoparticules	Embedded nanoparticles	Nanostructured materials	Elec/opto/meca nanodevices	Nano-bio devices
Very low+ low	14,7%	24,5%	34%	20,5%	23%
High+very high	81,4%	69,7%	57%	71,1%	63,7%
No answer	3,8%	5,8%	9%	8,3%	13,4%

Like in almost all sections of this first part of the questionnaire, priority is given to free standing nanoparticles (81,4%) and lower priority to embedded nanoparticles (69,7%) and nanostructured materials (57%). For responders, elec/ opto/ mecatronic nanodevices are the second priority for action targeted to citizens, before nano-bio devices. This result is not totally consistent with responders' perception of social acceptance but is in line with their perception of risk. Risk on personal data protection was previously considered as a major concern.[3]

For all kind of applications, the need for specific actions targeted to the citizens is considered as high or very high priority. The proportions of high or very high priority for action are always higher than the proportion of low or very low social acceptance, except for nanostructured materials where they are similar. Grounded or not, the scepticism or the opposition of a significant part of the public is perceived as a fact that challenges public authorities. This result will be fully confirmed in part 4 of this questionnaire.

2/ ENVIRONMENTAL APPLICATIONS OF NBIC TECHNOLOGIES

2.1 General results

The second part of the questionnaire focussed on environmental applications of converging technologies. Six categories of green NBIC technologies were considered:

- environmental monitoring (nanosensors, biochips, etc.)
- chemically active nanoparticles (like titanium dioxide)
- nanoporous membranes and filters (for air and water remediation)
- photovoltaic applications (such as Gretzel cells)

[3] See infra Chart 1.2 p 16

- nano-bio applications (microbiology inspired industrial processes and synthetic biology)
- molecular engineering

For each category, time horizon for industrial availability, environmental risks and benefits, and usefulness of public R&D support were considered.

General results are summarized in chart 2.1 next page.

Generally speaking, these applications are considered by a majority to have potentially high or very high benefits for the environment, which justifies high level of priority for public R&D funding. Associated risks are mainly considered high or unknown.

There is a clear distinction in the results between confined nanoparticles and nanostructures applications (such as nanofilters or photovoltaic cells) on the one hand, and applications based on the release of nanoparticles in the environment or biological midst (such as TiO_2 applications or synthetic biology) on the other hand. The first kind of applications are reputed significantly less risky than the second one.

Results in terms of industrial availability are in general consistent with the findings of the literature review[4], with a slightly optimistic inclination. Indeed, nanofilters for example, which are currently still laboratory prototypes, are considered industrially available. Similarly, the generalisation of nanosensors for environmental monitoring requires us to master nanotechnology and information technologies convergence, which is probably not possible in the short term.

2.2 Detailed analysis

Time horizon for industrial availability

Two categories of NBIC green applications are considered by a majority as already available: chemically active nanoparticles and nanoporous membranes. In order of industrial availability, the next applications are environmental monitoring, nanophotovoltaic cells, nano-bio applications and molecular engineering.

Based on the results of the questionnaire, we can build a "time horizon index": already existing, short term, middle term and long term answers are respectively weighted 1, 2, 3 and 4 to aggregate the results and calculate the index: the bigger the index, the further the time horizon for industrial availability.

The results are summarised in chart 2.2 below, with a comparison between experts and the whole panel.

[4] SKEP deliverable 6.2: *Converging technologies and environmental regulations, a literature review* (available online at www.skep-era.net)

NB: “Unk.” stands for Unknown and means that the current scientific knowledge is considered by the responder as clearly insufficient to answer the question.

The two most frequent answers are highlighted in red and yellow respectively

Chart 2.1: Environmental applications of NBIC technologies

	Industrial availability				Environmental risks					Environmental benefits					Usefulness of public spending in R&D			
	Existing	Short term (2012)	Middle term (2020)	Long term (2030)	Very low	Low	High	Very high	Unk.	Very low	Low	High	Very high	Unk.	Very low	Low	High	Very high
Environmental monitoring	20,4%	41,4%	15,9%	1,3%	13,4%	46,5%	9,6%	2,5%	17,8%	1,9%	6,4%	39,5%	31,2%	10,8%	1,3%	9,6%	54,1%	22,9%
Chemically active nanoparticles	68,2%	15,9%	3,8%	0,6%	0,6%	24,8%	28,7%	10,2%	26,8%	5,1%	27,4%	33,1%	8,3%	15,3%	7%	24,2%	49%	8,9%
Nanoporous membranes	44,5%	28,4%	7,1%	1,3%	18,1%	49,7%	5,8%	2,6%	14,8%	1,3%	6,5%	39,4%	36,8%	8,4%	1,9%	11%	59,4%	18,1%
Photovoltaic applications	12,8%	40,4%	19,9%	0,6%	8,3%	41%	9,6%	2,6%	21,2%	0,6%	5,1%	29,5%	40,4%	8,3%	0,6%	7,7%	46,2%	29,5%
Nano-Bio applications	5,7%	19,1%	30,6%	13,4%	0%	14,6%	28%	15,3%	24,8%	1,9%	14,6%	30,6%	8,9%	24,2%	5,1%	14,7%	41,7%	14,7%
Molecular engineering	1,9%	5,7%	19,7%	36,9%	0,6%	12,1%	15,3%	29,9%	29,9%	6,5%	17,6%	18,3%	7,2%	34,6%	12,7%	16,6%	30,6%	13,4%

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Chart 2.2: Time horizon index			
	All	**Experts**	**Non experts**
Chemically active nanoparticles	1,29	1,31	1,27
Nanoporous membranes	1,57	1,43	1,72
Environmental monitoring	1,98	1,98	1,97
Photovoltaic applications	2,11	2,17	2,05
Nano-Bio applications	2,75	2,60	2,91
Molecular engineering	3,42	3,37	3,54

We can observe some discrepancies between experts and non experts, but this is not significant enough to modify the chronology of green NBIC technologies. It is interesting to note that experts tend to be more optimistic regarding the short term availability of NBIC environmental technologies.

Perception of risks and academic background

The main disciplines of responders' academic background are split up into 4 groups: Chemistry, earth and life sciences, physics and computing sciences, and humanities. The perception of NBIC environmental risks vary significantly among these four groups, as we can see on chart 2.3 below.

Responders with a background in chemistry, earth and life sciences, physics or computing sciences have very comparable answers. Earth and life scientists are more inclined to consider that environmental applications of NBIC technologies pose a high or very high risk for the environment, and more often they answer that these risks are unknown. On the contrary, responders with a background in chemistry are the most optimistic about the lack of risks associated with these technological developments.

The major discrepancy in risk perception is between natural and physical sciences on the one hand, and humanities on the other. Responders with a background in sociology, philosophy, economics or law generally consider that environmental risks of green NBIC technologies are high or very high. They also use the answer "Unknown" more frequently.

Chart 2.3: Perception of risks and academic background

	All			Chemistry			Earth and life sciences			Physics and computing sciences			Humanities		
	High or very high	Low or very low	Unknown	High or very high	Low or very low	Unknown	High or very high	Low or very low	Unknown	High or very high	Low or very low	Unknown	High or very high	Low or very low	Unknown
Environmental monitoring	12,1%	59,9%	17,8%	2,9%	65,7%	17,1%	9,5%	61,9%	16,7%	9,6%	71,2%	15,4%	32,1%	28,6%	25,0%
Chemically active nanoparticles	38,9%	25,5%	26,8%	31,4%	45,7%	17,1%	42,9%	14,3%	33,3%	38,5%	28,8%	21,2%	42,9%	10,7%	39,3%
Nanoporous membranes	8,4%	67,7%	14,8%	5,7%	77,1%	14,3%	4,8%	64,3%	16,7%	7,7%	78,8%	7,7%	19,2%	38,5%	26,9%
Photovoltaic applications	12,2%	49,4%	21,2%	11,4%	60,0%	17,1%	14,3%	45,2%	21,4%	13,7%	51,0%	15,7%	7,1%	39,3%	35,7%
Nano-Bio applications	43,3%	14,6%	24,8%	31,4%	31,4%	20%	47,6%	2,4%	33,3%	50%	15,4%	19,2%	39,3%	10,7%	28,6%
Molecular engineering	45,2%	12,7%	29,9%	34,3%	28,6%	22,9%	47,6%	2,4%	35,7%	48,1%	15,4%	28,8%	50,0%	3,6%	32,1%

NB : for each academic background, the two environmental applications of NBIC with highest level of risks are highlighted in red and yellow respectively.

Benefits/risks ratio

Very low, low, high and very high answers are weighted respectively 1, 2, 3 and 4 to calculate an average benefits/risks ratio. A ratio above 1 means that perceived environmental benefits outweigh the risks. The results are summarised in chart 2.3 below, with a comparison between public sector, private sector and civil society. No answer and "unknown" answers are not considered in the following analysis.

Chart 2.3: Benefits/risks ratio

	Civil society	Private sector	Public sector	All
Environmental monitoring	Risks: 2,33 Benefits: 3,43 **Ratio: 1,47**	Risks: 2 Benefits: 3,31 **Ratio: 1,66**	Risks: 2 Benefits: 3,25 **Ratio: 1,63**	Risks: 2,02 Benefits: 3,27 **Ratio: 1,62**
Nanoparticles	Risks: 3,2 Benefits: 2,14 **Ratio: 0,67**	Risks: 2,91 Benefits: 2,56 **Ratio: 0,88**	Risks: 2,71 Benefits: 2,65 **Ratio: 0,98**	Risks: 2,75 Benefits: 2,60 **Ratio: 0,95**
Nanoporous membranes	Risks: 2 Benefits: 3,38 **Ratio: 1,69**	Risks: 1,87 Benefits: 3,32 **Ratio: 1,78**	Risks: 1,91 Benefits: 3,33 **Ratio: 1,74**	Risks: 1,91 Benefits: 3,33 **Ratio: 1,74**
Photovoltaic applications	Risks: 2,22 Benefits: 3,37 **Ratio: 1,52**	Risks: 2,45 Benefits: 3,32 **Ratio: 1,36**	Risks: 2,04 Benefits: 3,33 **Ratio: 1,63**	Risks: 2,1 Benefits: 3,33 **Ratio: 1,59**
Nano-Bio applications	Risks: 3 Benefits: 2,25 **Ratio: 0,75**	Risks: 3 Benefits: 2,5 **Ratio: 0,83**	Risks: 3,01 Benefits: 2,92 **Ratio: 0,97**	Risks: 3,01 Benefits: 2,83 **Ratio: 0,94**
Molecular engineering	Risks: 3,67 Benefits: 2,2 **Ratio: 0,6**	Risks: 3,45 Benefits: 2,25 **Ratio: 0,65**	Risks: 3,23 Benefits: 2,57 **Ratio: 0,8**	Risks: 3,29 Benefits: 2,53 **Ratio: 0,77**

Environmental monitoring using nanosensors or biochips, nanoporous membranes used for water or air decontamination, and photovoltaic applications are considered the most potentially beneficial applications of NBIC technologies for the environment. They are also the categories of green NBIC with the highest benefits/risks ratio. Nanoparticles, nano-bio applications and molecular engineering are considered the most hazardous technologies, and the risks associated with these technologies are seen as outweighing their benefits.

The results are consistent through the three categories of stakeholders, with no significant differences. In general, civil society members tend to be more severe in their judgement of NBIC green technologies. The private sector makes a genuine evaluation of potential risks and benefits of NBIC environmental application, with no significant discrepancies with other stakeholders. The highest benefits/risks ratios are obtained in general with public sector responders. Further analysis of the data shows that on average the scientific community (both private and public researchers) tends to overestimate both potential risks and benefits for all green NBIC applications in comparison with non scientists. Benefits/risks ratio are however very close.

What we do not know

One possible answer in the questionnaire is "unknown" and refers to the fact that current scientific knowledge is clearly insufficient to answer the question, for example because we do not know enough to assess potential risks or benefits of some NBIC technological developments. For public authorities and public research funders, what we do not know is clearly of major significance.

As we can see on chart 2.1 above, environmental risks of converging technologies are considered unknown by a majority of responders. Of course, this is particularly true for NBIC technologies that are expected to be available in the long term (such as molecular engineering or nano-bio applications). But scientific knowledge is considered insufficient even for already existing technologies such as nanoparticles, which is a graphic illustration of knowledge gaps and under investment in risk assessment.

To go further, we can focus on risks associated with environmental monitoring, nanoparticles and nano-bio applications to perform cross analysis of the proportion of unknown answers. Results are presented in chart 2.4 below.

In general , members of the scientific community (both private and public research) are more inclined to consider that the environmental risks of NBIC technologies are unknown. This is no surprise as they have a better view of current scientific knowledge and a rational self interest in pledging for further research. It is interesting to note that private sector responders consider that environmental risks of NBIC technologies are unknown in a significantly larger proportion than other stakeholders. This could be interpreted as a general trend of developers to underestimate early warnings and potential risks of emerging technologies, the lack of scientifically established adverse effects being used as a proof of lack of risk. The public sector is by far more optimistic on the level of scientific knowledge about benefits and risks of NBIC technologies. This is very surprising considering the lack of scientific knowledge on these issues owned by both scientists and developers, and this could be a concern for evidence-based policy implementation.

Chart 2.4: Proportion of unknown answer

	Scientific community	Non scientists	All	Civil society	Private sector	Public sector
Nanoparticles risks	30,4%	20%	26,7%	40%	42,8%	23%
Nano-Bio applications risks	29,4%	16,4%	24,8%	30%	47,6%	20,6%
Environmental monitoring risks	17,6%	18,2%	17,8%	30%	28,6%	15,1%

Public support for R&D

NBIC technologies have enormous potential for environmental benefits, from energy production and storage to pollution remediation. There is a risk of not harvesting this potential, for example because environmental applications may be less profitable than others. Public funding for research and development can prevent this problem by identifying and pushing the most promising green NBIC technologies but priorities must be set.

Chart 2.5: Proportion of high or very high prioirty for public R&D

	All	Civil society	Private sector	Public sector
Environmental monitoring	77,1%	60,0%	81,0%	77,8%
Nanoporous membranes	76,4%	80,0%	85,7%	74,6%
Photovoltaic applications	75,2%	80,0%	81,0%	73,8%
Nanoparticles	58,0%	40,0%	52,4%	60,3%
Nano-bio applications	56,1%	30,0%	61,9%	57,1%
Molecular engineering	43,9%	20,0%	33,3%	47,6%

All in all, NBIC applications to standard green technologies such as photovoltaic cells, remediation of air and water or environmental monitoring are considered the highest priorities for public support to R&D. They are also the categories of environmental applications with the highest benefits/risks ratio. On the contrary, the most futuristic and less familiar applications of NBIC technologies in the questionnaire (such as nano-bio or molecular engineering) are not seen as a priority, maybe because their potential benefits are difficult to grasp. The case of nanoparticles is particularly interesting as it is the only green NBIC technology currently available and deployed on pilot sites. It is not considered as a priority for research and development, which could be interpreted in two different ways: on the one hand , one can consider that public support is no longer needed for a mature technology but on the other hand, nanoparticles applications, according to a majority of responders, have shown very few benefits for significant risks.

Most of the results are between 50% to 80% of high or very high priority for public support to R&D, even for technologies with a bad benefits/risks ratio. This means that there is no clear consideration of priorities for public funding by the majority of responders.

There are some differences between civil society, private sector and public sphere responders, but they are not significant enough to modify the general conclusions above. Logically, private sector responders are the most in favour of R&D, except for nanoparticles (already mature technology) and molecular engineering (probably too futuristic). Civil society responders are the most severe in their appreciation of benefits risks ratio of NBIC technologies (chart 2.3 above) and consistently less inclined to support public support for research and development.

2.3 Additional application and comments

At the end of this second part of the questionnaire, an opportunity was given to responders to add another kind of green NBIC technology and to make comments.

Six applications were proposed in two main areas: energy and ambient intelligence. Indeed, NBIC technologies show significant potential for energy production and storage. Hydrogen production and renewable energy technologies could benefit from radical improvements in the short term according to the responders. Significant progress in terms of energy storage and savings was also mentioned. All these energy applications are deemed to present high benefits for the environment and low to very low associated risks according to responders. Other additional applications were linked to nanotechnology and information technology convergence. Besides environmental monitoring, responders consider that ambient intelligence systems will emerge in the middle term thanks to the generalisation and networking of nanosensors featuring computing and communication capacities. Benefits risks ratio of this technology is considered very positive.

About 25 comments were made in this part of the questionnaire and three major points are made.

First, some responders consider that the categories used in this part of the questionnaire were too broad to properly assess potential risks and benefits of NBIC applications. For the same kind of green NBIC application, risks can vary significantly with different technological solution, through the life cycle of products and according to different regulation framework. For example, nanostructured catalysers do not seem to present major risks for human health or the environment as nanoparticles are used in a confined device. But risks could arise in the end of life of these products and the release nanoparticles into the environment . Such a risk obviously depends on waste management regulation and the kind of nanomaterial used.

Other comments point out that many of the proposed environmental applications are promoted as responses to man-made environmental problems and suggest that rather than looking into the unknown for responses we should focus on not creating such problems in the first place.

Lastly, some responders emphasise that scientific knowledge is insufficient to address both the risks and benefits issues of green NBIC technologies. These remarks are very consistent with the high level of "unknown" answers presented and discussed above. Further research (both R&D and fundamental research on risks) is called for by many responders. For some responders taking into account futuristic applications of NBIC technology such as synthetic biology or molecular engineering is mixing science and science fiction.

3/ NEEDS AND OPPORTUNITIES FOR PUBLIC REGULATION

3.1 General results

The third part of the questionnaire was dedicated to public regulation of NBIC technologies, with a focus on environmental regulation. This part of the questionnaire was articulated around 7 main regulating functions:

- Labelling and certification for consumers' information
- Traceability of nanocomponents through the supply chain
- Liability reinforcement of producers, distributors and importers
- Adapting REACH
- Waste management
- Emissions norms
- Workers' exposure

The need to adapt existing regulation and the main obstacles to do so were the core of the questioning. General results are presented in chart 3.1 below.

Chart 3.1: Public regulation of NBIC technologies

	Neeed to adapt current regulation		First obstacle	Second obstacle
	Yes	No		
Labelling	69,4 %	14 %	Insufficient scientific knowledge	Lack of citizen awareness
Traceability	73,9 %	9,6 %	Lack of technical means	Impact on European competitiveness
Producers' liability	59,1 %	14,9 %	Lack of political will	Lack of citizen awareness
Adapting REACH	66 %	7,1 %	Insufficient scientific knowledge	No common classification scheme
Waste management	66,2 %	14,6 %	Insufficient scientific knowledge	Lack of technical means
Emissions norms	60,9 %	17,3 %	Insufficient scientific knowledge	Lack of technical means
Workers' exposure	71,2 %	15,4 %	Insufficient scientific knowledge	No common classification scheme

Only the most often quoted first and second obstacles are presented in the chart above (another way of analysing the results about these obstacles, more representative of the diversity of answers, is used in chart 3.4 below)

3.2 Detailed analysis

Priorities in terms of regulation

Chart 3.2: Adaptation of current reguylatory framework

	Civil society		Private sector		Public sector	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Labelling	60 %	30 %	71,4 %	4,8 %	69,8 %	14,3 %
Traceability	70 %	10 %	85,7 %	0 %	72,2 %	11,1 %
Producers' liability	60 %	20 %	71,4 %	4,8 %	56,9 %	16,3 %
Adapting REACH	70 %	10 %	81 %	0%	63,2 %	8 %
Waste management	60 %	20 %	76,2 %	4,8 %	65,1 %	15,9 %
Emissions norms	40 %	30 %	61,9 %	19 %	62,4 %	16 %
Workers' exposure	50 %	20 %	71,4 %	14,3 %	72,8 %	15,2 %

All dimensions of the current regulatory framework have to be adapted according to a large majority of responders in all special-interest groups.

The priorities, in terms of regulatory framework evolutions, vary significantly from different stakeholders' point of view. Civil society and private sector responders have very similar answers, with a high priority on traceability improvement and adaptation of REACH legislation. They also consider waste management and producers' liability as significant issues. Less responder from civil society and private sector, but still the majority, consider that workers' exposure legislation and emissions norms have to evolve. It is interesting to note that private sector responders are very supportive of regulatory evolution, and even the most in favour of such an evolution in all but one dimensions (worker's exposure). A new regulatory framework is preferred to current legal uncertainties and juridical insecurity.

There are important discrepancies between public sector responders and the rest of the panel. All in all, public sector responders are less inclined to consider that regulatory framework evolutions are needed. They also organise the priorities in a different hierarchy of regulatory framework evolutions For example, a much lower proportion of public sector responders consider that REACH or producers' liability rules should be modified.

The public sector group gathers both operational staff from public administration such as ministries or environment agencies and scientists form public research organisation. These two sub groups have different answers on public regulation of NBIC technologies, as we can see on chart 3.3 below. No answer is systematically 5 to 10 points higher for public scientists than operational staff, and this mechanically reduces the proportion of positive responses. This fact could be interpreted as a reluctance of scientists to take a position on regulatory issues. More surprising is the fact that the level of no response is also very high among operational staff, which reveals a high level of uncertainty about regulation needs and opportunities within ministries and public agencies.

Chart 3.3: Public sector responders and adaptation of current reguylatory framework

	Operational staff from ministries and public agencies			Scientists from public research organisation		
	Yes	**No**	**No answer**	**Yes**	**No**	**No answer**
Labelling	73 %	16,2 %	10,8 %	68,5 %	13,5 %	18 %
Traceability	75,7 %	10,8 %	13,5 %	70,8 %	11,2 %	18 %
Producers' liability	58,3 %	22,2 %	19,4 %	56,3 %	13,8 %	29,9 %
Adapting REACH	70,3 %	5,4 %	24,3 %	60,2 %	9,1 %	30,7 %
Waste management	62,2 %	13,5 %	24,3 %	66,3 %	16,9 %	16,9 %
Emissions norms	62,2 %	16,2 %	21,6 %	62,5 %	15,9 %	21,6 %
Workers' exposure	73 %	18,9 %	8,1 %	72,7 %	13,6 %	13,6 %

Major obstacles to efficient regulation of NBIC technologies

We can aggregate the answers about the two main obstacles to different regulatory dimensions evolution by weighing first obstacle and second obstacle answers by 2 and 1 respectively and then summing up. The higher this index is, the more often the obstacle is quoted as a serious difficulty. Results are presented below.

Chart 3.4:Obstacles to regulatory framework evolution

	Insufficient scientific knowledge	Lack of technical means	No common classification scheme	Impact on European competitive - ness	Lack of citizen awareness	Lack of political will	Other
Global (average)	81	69	60	39	31	84	4
Labelling	95	45	83	40	39	84	6
Traceability	49	100	71	41	35	100	9
Producers' liability	38	41	56	61	32	82	6
Adapting REACH	96	61	75	33	21	82	0
Waste management	85	69	50	27	39	91	2
Emissions norms	97	67	37	35	24	80	3
Workers' exposure	105	100	45	36	30	68	3

According to responders, there are clearly two major obstacles to necessary evolutions of current NBIC regulatory framework: insufficient scientific knowledge and lack of political will. The lack of technical means is also often quoted, especially in relation to metrology issues.

A cross-analysis by group of stakeholders is presented in chart 3.5 below. This index is calculated by weighing first and second obstacle answers by 2 and 1 respectively, summing up and dividing the result by the size of each stakeholders group to make them comparable.

Chart 3.5:Obstacles to regulatory framework evolution

	Insufficient scientific knowledge	Lack of technical means	No common classification scheme	Impact on European competitive - ness	Lack of citizen awareness	Lack of political will	Other
Civil society	2,7	3,1	2,8	1,6	0,8	3,4	0,2
Private sector	3,2	2,1	3,0	1,4	1,6	4,4	0,2
Public sector	3,7	3,3	2,6	1,8	1,4	3,7	0,2

4/ PRIORITIES FOR ACTION AND RESEARCH

In the fourth part of the questionnaire, people were asked to specify two priority actions from public authorities and two priority topics for public research. These open questions have been coded to allow quantitative analysis. However, analysis in this part will be mainly qualitative in order to benefit from the full scope of responders' insights.

4.1 Priority actions from public authorities

The aim of the first question ("Priority actions from public authorities") is to compare different kinds of actions from public authorities. The answers have been coded as follows:

- public information (PI)
- public participation (PP)
- public research (PR)
- public research on risks (RR)
- market regulation (M)
- public regulation (PR)

These categories have been summarized in three groups:

- actions targeted towards the **public** (PI + PP)
- **research** including research on risks (R + RR)
- public **regulation** (PR – M)

The final output of the whole SKEP WP6 (literature review, questionnaire and workshop) is to make recommendations for future research about CTs and the environment and to contribute to the design of the third join call for research of the network. However, it appears necessary to weight the public research financing priority with other priorities indicated through this questionnaire. In fact, **"public research" appears to be a priority, but the least important one**. Public research is a priority for 22.2% of the responders, after regulation (29,9%) and far beyond "action targeted to the public" (46,2%).

Chart 4.1 : Priority actions from public authorities			
Public information (PI)	28,7%	**Total for action towards the public**	46,2%
Public participation (PP)	17,5%		
Public research (PR)	12,0%	**Total public research**	22,2%
Public research on risks (RR)	10,2%		
Market regulation (M)	0,4%	**Total public regulation**	30,9%
Public regulation (PR)	31,3%		

These different groups of action are now analysed in a qualitative way, starting with with the highest priority, "actions targeted toward the public".

Actions targeted toward the public

The "public" relationship with technological developments can take several forms, from being mere end-users to having decision-making ability. Five distinct levels of implication can be considered[5]: informing (1), listening to (2), discussing (3), involvement of (4), in partnership with (5). The first one is public information.

Public Information

28.7% of responders consider public information as a priority and call for "*information*", "*information to general public*", "*Public information*", "*More information to everyone concerned*", "*public awareness*", "*lead information campaigns aimed at the public*".

The justifications of this concern are:

- the public, who are also the consumers (and the voters), have to accept or pay for CT products. This is the theme of public **acceptability**: *"to define what could be acceptable for the public in term of Nano Technology development".*

[5] We are using here the typology used by the National health programme in Canada (2000)

- the public has also the **right** to be informed when they are directly concerned, especially on *"risk assessment and safety in the uses.", "Information on 'What is this 'Nano' especially in the fields of food and medicine (where everyone has a personal relation*)", "*Public involvement is certainly a top priority: in order to allow citizens to know what is going on, to form their proper opinion, and to react adequately to the new challenges they are confronted with (for instance, to learn to know what kind of information is relevant for their personal situation, to learn how to handle new technologies prudently, and so on)*"

If the public has to be informed, responders have similar opinions about the right content of the information to be provided. Some insist on:

- the benefits (3 cases): "*promote use of these technologies for improving public environment and infrastructures*". "*Information: nanoparticles and other objects created by nanoscience do not differ fundamentally from what exists now in "classical" technology, they just perform some functions better*". The communication is then promotion.
- the risks (1 case): "*Inform the public of what is known about the potential risks*"
- the balance between risks and benefits (4 cases): "*Information on potential benefits and risks*", "*The public should have sufficient information on both risk and potentiality of the converging technologies*", "*Better information of public about risks but also benefits of nanotechnology*", "*Clear information on sustainable use of nanotechnology and what is done to keep the remaining risk as low as possible is necessary*"

The perception of good information content differs from one respondent to another but a common point can be found in the fact that the questions this information is supposed to answer do not come from the public. In this perspective**, information goes from the experts *"towards the public"*: and as such it is a *"communication"* scheme**. This leads to two questions. The first one is: where the information is coming from and how it is provided to the public? The second is: Should general public involvement include the definition of questions and issues to be considered regarding CTs development ?

"the public needs to be informed in a correct way" , the quality of information that should be provided depends for the responders on its scientific grounds ("*information of public on scientific bases*"). This scientific information has to be relevant through a "*system of updated information*". In this communication scheme, **the information comes, first of all, from scientists**.

As the public are not scientists, information has to be adapted accordingly: "*Concrete examples*", "*education*", "*A kind of ranked information on materials, their possible exposure and hazard is necessary to keep information as informative and logic as possible*". At the same time this information transmission implies to "*create incentives for researchers and experts to get involved in public information/debate about converging technologies*". **The circulation of information from scientists to the public implies that both exert some effort**.

The scientific basis for the information shared is justified by the **risk of misinformation or ideology.** Respondents make clear reference to the GMO case for this point: "*Inform people to allow for rational discourse. E.g. the discourse on genetically modified maize was and is irrational. The main effect of this behaviour was to prevent e.g. modified vitamin-A enriched rice to reach the 3rd world, resulting in blindness for tens of thousands. This needs to stop - discourse must be taken to a rational level*". Scientific objectivity is aligned with acute precision, which implies to make distinctions. In this respect, the term of "converging technologies" but also "nanotechnology" are discussed "*Make clear the differences between nanoparticules and embedded nanodevices*", "*distinction between different areas of use in discussion*". "*Undertake an informed information campaign so the public are not misinformed on the subject*", "*to enable clear position to be established, and sound basis on which to base decisions*", "*About public awareness, there is presently a wave a irrational rejection involving a confusion between totally different topics: nanoparticles, GMO, robotics, information technology and internet. In this respect, promoting the very concept of "converging technologies", which is more a gimmick than an operational reality, is probably not a good idea. A strong pedagogical effort towards the public, explaining the different underlying fields in simple worlds, is certainly necessary*", "*type II research in the sense of Nowotny in order to avoid a complete control of technical progress by ideologists... and media*". Here, **scientific objectivity appears to be the solution to the confusion and irrationality of the public debate**[6]. Then, the question of scientific objectivity still depends on the how **independently scientific information was produced**: "*Laymen information*", "*funding for independent (peer- reviewed) research projects in the field of human health and environmental impacts", "create agencies monitoring the emergence of technologies and assessing associated environmental risks".* This last question is a governance one.

Public participation

17,5% of the responders consider that public involvement is necessary :

- level 2 and 3 (listening to and discussing with the public): "*Discuss with people*", "*public discussion*"
- level 4 (involving the public): "*Public debate*", "*more information based on more public involvement*", "*engaging the public in discussions on regulation options (both for end of line products but also for research directions)*", "*public involvement including staff of the labs*", "*dialogue with the public*", "*Public involvement is also very relevant for the promoters of new technologies in order to question and to found the decisions they are making while performing their R&D activities, in order to become more socially responsible when building out their professional networks and their contacts with public*

[6] See also this comment: *"I have been strongly involved in several public meetings about this topic since the last 3 years. One of the main difficulties of the debates is to stick to scientific knowledge compared to wishful thinking and science fiction based reasoning. Most of nano-xxx stuff is research, and this is where we must preserve freedom of thought. Debates cannot be done "in general". A principle of reality is to stick to existing materials, devices, etc. Laws must rely on human ethical principles and be kept at this level."*

authorities, and so on". Here, public involvement is not only related to acceptability or public rights but also economic efficiency and producers' responsibility.

- level 5 (partnership with the public): Here, at the other end of the spectrum of the communication from science to society scheme, the public have some ability to control the development of science: "*Engage public participation*", "C*oncertation with citizens*", "*more opportunities for discussion and influence in decision-making*".

The role of the public in science and technology governance is a political choice. The first justification for a large-scale participation of the public in CTs development and regulation is based on a particular conception of democracy: *"the potential of nanotechnologies to transform the global social, economic, and political landscape makes it essential that the public fully participate in the deliberative and decision-making processes".* Public involvement refers to **participative democracy** as a solution to the limits of representative democracy. From this perspective, the public is one of the stakeholders that must get involved in a **collective decision making process.** The involvement of various stakeholders aims to diversify the points of view and the interests involved. This is seen as a way to question the means and the finality of technological developments: "*Engagement in decision making process about whether regulation, labelling etc are required. This decision making process to involve all interested parties e.g. business, regulators, ngos etc*", *"A second priority is a substantiated research policy to make sure that new technological applications are - on an abstract level - not only socially robust, but are also - on a concrete level - societally embedded in a socially robust way."*, "*engaging multiple stakeholders in intelligent and coordinated agenda setting (e.g. converging technologies for clean water, converging technologies for distributed collection, storage, and use of energy)" "- organising platforms for the exchange of knowledge between all stakeholders (including producers and public)*". This collective process implies "*more participation of experts in social sciences and humanities*!" *"EHS research financial support reinforcement" "increasing support of ELSA projects"* .

Finally, public consultation can also be **mere politics**: "*Follow the advice of the European CTEKS report by Nordmann and al. in using minority public resistance as a resource for precautionary action*"**. However, not only the regulation of CTs developments but public and stakeholders deliberations can also be threatened by CTs developments themselves ???** "*Regulation and public involvement. And both should be energised by an awareness of the potential for technological convergence to outpace our deliberative systems*".

<u>*Public regulation*</u>

The second priority is regulation from public authorities. 31.3% of the responders quoted some public regulation actions (PR). One responder (0.4%) indicates *"not over regulating the market"* (M). We assume that the total is (PR-M) 30.9% of responders are expecting public regulation actions.

Responders insist on the necessary **adaptation of existing regulations** even if this can imply an endless effort: *"adaptation of regulations", "Adaptation of existing regulations", "clear regulation",* *"formulation of regulations", "Substantial regulatory changes in existing laws are necessary in order to adequately and effectively address the fundamentally different properties of nanomaterials and new challenges that they present.", "set up an open, transparent, consistent and adaptative framework for NBIC technologies development", "Continuous efforts on adjusting regulations",*

Some of the responders indicate the field or the content of regulation measures. Considering these details, one can **list the features of a desirable regulatory framework that will by contrast enlighten some inadequacies or gaps in current regulation**.

First, **risks appear to be a common concern.** One responder points out *that "besides the potential risk of FUTURE nano products, one should worry more about the high risk of CURRENT carbon nanoparticles associated with fuel combustion."* Not surprisingly, sanitary, health risks are more frequently referenced than environmental ones: *"healthcare", "Regulation - to control use until proven safe", "producing as soon as possible regulation on exposure and human health safety", "Public regulation for safe use and waste(in industrial producing and manufacturing products including Nano)", "need for a norm for the toxicological risk of nano-object", " adapt existing regulation (particle emissions, reach, ...) to environmental risks of nano-particle emissions", " adapt existing regulation (workers protection) to health risks of nano-particle emissions".* In order to correctly assess these risks, a **life cycle analysis perspective** is called for: "*regulation of generation, use and disposal of nanomaterials" " adapt existing regulation (particle emissions, reach, ...) to environmental risks of nano-particle emissions", "a systematic environmental assessment (by LCA approach) and sanitary risk assessment for each nanoparticule / nanotechnology", "perform transparent life cycle assessment (with inclusion of risk evaluation)with products and product applications*."

Clear references to **REACH** are provided. The recent European regulation on chemicals is considered insufficient to regulate current and future nano and converging technologies: *"adapting REACH", "the EU has to make up its mind concerning nano and REACH", "elaborate annex 17 Reach with a sub regulation for nano-applications of substances", " Consider nanoparticles to be new chemicals". "Traceability*" is also quoted, and leads us to the issue of relations between producers, distributors and consumers. Some consider that industries should produce information on risks, share it with public authorities and consumers (including through labelling of products), *"collect information from industry on the use of converging technologies, applications for consumers or in agriculture", "To ensure manufacturers undertake appropriate risk assessment for any substance (including nano materials) and then demonstrate the risks are managed", "oblige producer to provide human health and environmental risk on there new products", " adjust subsidizing schemes to include a mandatory expenditure (10-15%) on risk management", " foster transparency of safety data for nanomaterials (e.g. adaptation of REACH, etc.)", "provide product information for consumers", "Common labelling of products containing nanoparticles".*

Most of the comments focus on risks and REACH. Very few comments deal with other topics such as personal data protection: "*Ensuring that data protection laws cannot be circumvented easily on a* *technological level, by forcing fail-safes on RFID technology (e.g. by destroying tags when leaving a shop Few* comments concern law, taxes or politics: *"Law against pollution on a nano scale", "Nanotaxes for environmental safe", "Political will", "stop business on depollution who pollute in reality".*

The last important group of answers is related to **governance** issues. Here, the stakes are the organisation of the whole process of regulation, its scale and **the interactions between regulation and science**. For some responders, the question of the scale of regulatory framework is an issue in itself and they plead for **more international cooperation**, from the European to the global level: *"act at the European level, in close collaboration with national authorities", "intra-Europe", "collaboration (also with industry)", "Clear regulation at the international level (EC, USA, and Asia", "international co-operation (such as within the oecd and the irgc)on matters of research and regulation of nanotechnologies", "Homogenize international regulations about risk classification and monitoring techniques", "Establishment of international standards".* A global approach is justified by consideration of market distortions but also by the complexity and immensity of work to be done to assess and regulate current and future technological developments[7].

As for the relationship between the public and the scientific community, some responders insist on **regulations based on scientific knowledge**, especially for risks: *"Scientifically based evaluation", " cost/benefit analysis", "Develop a risks analysis methodology based on facts*", *"Research and Regulation, then Information and Participation", "increase spending on impact assessment[…]and then adapt the law", "the one and only priority: having the right focus on the environmental impacts of converging technologies ... it is investing in the development of a correct methodology for the assessment of risks before taking any action in the field of regulation. […] Meanwhile taking care with the necessary pre-caution which according to my knowledge is certainly the case for the production of nanomaterial in Belgium".*

On the contrary, some responders plead for precaution before we have complete scientific knowledge. Here, the "prevention" strategy is considered unworkable due to scientific uncertainty and a precautionary approach should be implemented. As a consequence, regulatory action is prior to stabilised scientific knowledge: *"implementation of the precautionary principle", "application or the precautionary principle in regulation", "Strict regulation following recommendations by scientists, sociologists, and philosophers, always favouring precaution over risk", " Precautionary approach to applications involving the widespread release of these materials to the environment."* the precautionary principle implies to take measures in case of potential risk even if complete scientific knowledge is missing. One responder has called for a moratorium: "*Until a regulatory framework is created or the existing legislation is adapted a moratorium must be put in place on the release of nanomaterials and the use of nanotech applications."* One responder even calls for a more radical approach : *"Recognise and address the problem of strict uncertainty by*

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[7] See also this comment « *Key issue is how to get European countries to collaborate together better and allocate research areas without major overlaps. Overlapping research is huge in Europe; resources should be focussed more precisely."*

developing novel principles of regulation that are precautionary beyond what can be achieved by the "double negative" of Rio and the EC definition of the precautionary principle (that is, a principle that requires that precautionary measures have to be "cost-effective" as defined within a market logic)." Scientific and technological governance is a very controversial subject, involving technical, cognitive and political aspects. The question of the good governance of scientific and technological developments can be a clear point of dispute. What is at stake is not only choosing the means or taking measures but the cognitive frame of decision-making itself.

<u>*Public Research*</u>

The third priority action pointed out by responders is public research (22.2%): *"Research", "Scientific knowledge", "more research", "support of public research", "money for research", "research funding", "Increased R&D ", "gaining more technical knowledge/data", "support scientific research", "generation of facts", "basic scientific research", "more publicly basic research", "Support research (notably at industrial processing and waste levels)"*. Public research is only the **third priority according to responders**, after regulation and actions targeted to the public.

Nearly half of the answers referring to research specifically mention research on health and environmental risks (10,2%): *"more research on risks and benefit", "Support more research into the favourable and less risky aspects of NBIC technology", "To have more scientific information about dangers", "Develop research on risks", "safety research", " financing research to increase knowledge about risks", "develop REAL scientific knowledge about risks exposure", "subsidies for risk evaluation in parallel to nanomaterial development", "Fostering research on impacts of new materials and technologies", "find out whether there will be negative environmental impacts (to fund studies on the risk assessment of nano- and CT materials/devices and their potential negative impact on human health and environment)", " Convergent research to evaluate, to measure the risks for health and for environment, being exposed to Nano", "Research on the implication for Environmental safety and human health" "increase funding for research on environmental impacts", "Finance research that elucidate the behaviour in the environment"*

Developments in **toxicology, ecotoxicology but also metrology** are also expected: *"Toxicology and ecotoxicology knowledge development", "knowledge of impacts (toxico-ecotoxico)", "Finance research that elucidate ecotoxicity", " funding research on toxicology and metrology", "To get accurate Toxicology developed on such materials. The lack of knowledge is a barrier to the development of this new part of science and may lead to over or under estimation of the true risk.", " Development of standards to allow measurements of nano materials, releases, concentrations in the environment etc."*

Responders identify the need for research on the risk itself but also for **risk assessment**: *" risk assessment", " definition & adapted risk assessment", "Developing risk management strategies", "Development of risk assessment methodologies" , "More research to understand exposure and hazard to allow a comprehensive risk assessment for each nanomaterial", "Development of methods for risk* *assessment of nanoparticles", "Funding of R&D to investigate the risks, to develop methodologies and devices to handle especially nanoparticles (e.g. measuring devices usable in indusial workplaces)"*

This result is consistent with the priority regulation measures previously analysed and with the results of the first three parts of the questionnaire: **risks are a transverse priority for regulation, research and relations with the public**.

We do not analyse the research topics quoted in this question in detail here since the second question of this part of the questionnaire is dedicated to the two priority research topics. The detailed information gathered here will help to complete information gathered in the next question.

4.2 Priority research topics

In the second question of part IV of the questionnaire, responders are asked to provide two priority topics for public research. This open question has been coded as follows:

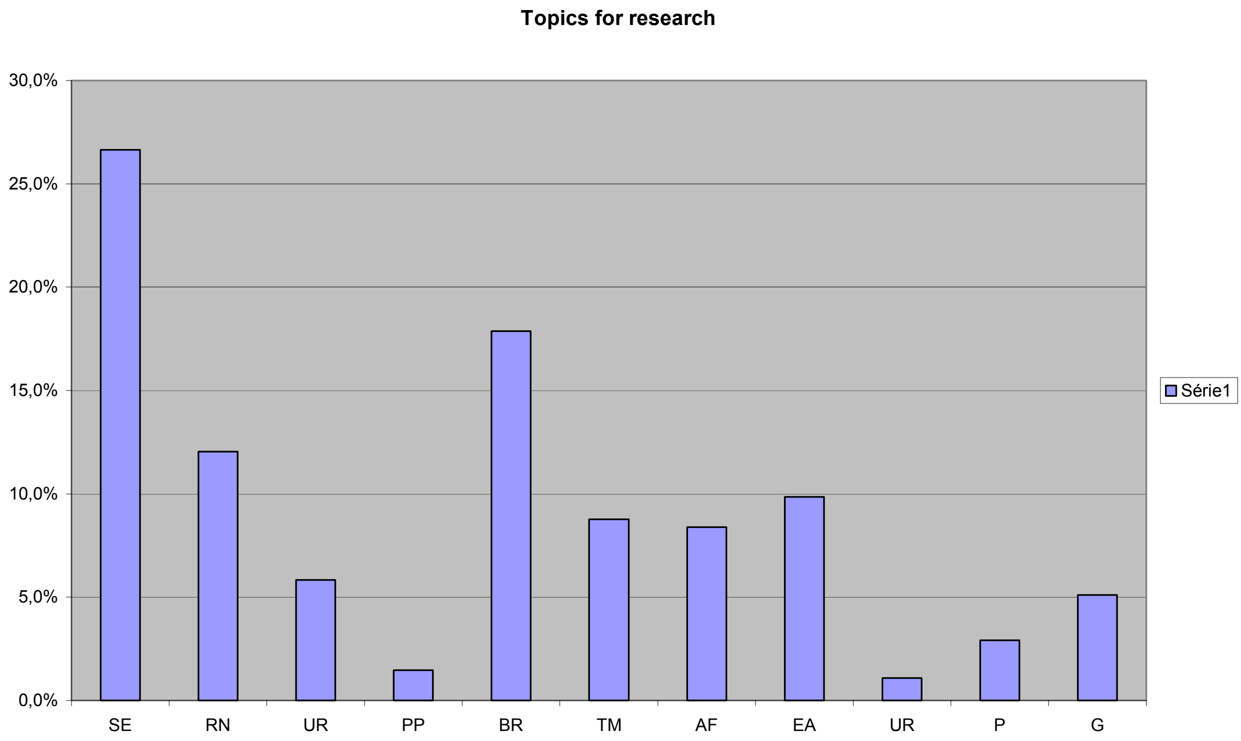
- **UR: unspecified risks**
- **SE: health or environmental risks**
- **RN: specific risks of nanotechnology**
- **PP: personal data protection**
- **FR: fundamental research (including methodologies of risk assessment)**
- **TM: research on technical means**
- **SD: specific domains of application**
- **EA: environmental applications**
- **UR: unspecified regulation**
- **P: public involvement**
- **U: utility assessment**

These categories have been summarized in four groups:

- **Research on risks: UR+SE+RN+PP**
- **Prerequisites for research on risks: FR+TM**
- **Applications: SD+EA**
- **Governance: UR+P+U**

The list of the topics quoted draws a research programme for public authorities. Even if *"all are important"*, the frequency of the quotes can be interpreted as a degree of importance given to each topic.

Chart 4.2: Priority research topics			
Health or environmental risks (SE)	26,6%	**Research on risks**	46,0%
Risks related to nanotechnology (RN)	12,0%		
Unspecified risks (UR)	5,8%		
Personal data protection (PP)	1,5%		
Fundamental research (FR)	17,9%	**Prerequisites for research on risks**	26,6%
Technical means (TM)	8,8%		
Specific domains of application (SD)	8,4%	**Applications**	18,2%
Environmental applications (EA)	9,9%		
Unspecified regulation (UR)	1,1%	**Regulation and governance**	9,1%
Public involvement (P)	2,9%		
Utility assessment (U)	5,1%		



Qualitative analysis combined with quantitative insights help us to elaborate a public research agenda.

Research on risks:

A clear majority of answers (72,6%) refers to research on risks (46%: risk in general, risks for human heath, risks for the environment, personal data protection) and prerequisites of research on risks (26,6%). This result is consistent with the results of the previous parts of the questionnaire. Some CTs developments are perceived as potentially harmful for human heath and the environment (part 1). Even "green applications" are considered as potentially risky, with half of them (three on six) presenting a negative ratio benefits/riks (part 2). 10,2 % of the responders also consider research on risks as a top priority for public authorities (part 4-1). This priority given to research on risks can be interpreted in three different ways. Research on risks can be important because CTs are potentially dangerous. , For example, one responder considers that past history of technological development clearly show the need for risk assessment : *"Do not repeat the errors of the past: manufacture million tons of highly toxic pesticides & similar which are finally released in water & soil for years before anyone start to wonder whether this is a problem."*

Research on risks can also be important because there is very little research on risks undertaken so far. Responders might consider that too few has been dedicated to risks compared to development of CTs and that a better balance has to be reached. In fact, three responders have insisted on the fact **that risk assessment should be undertaken at the same time than the development of**

nanotechnologies and CTs: *"Nanotoxicology studies at every stage", "both themes should be addressed equally [European competitive green technologies] and increase research on risk assessment and management (…)","A second priority is mainstream R&D activities so that risk and uncertainty research is an inherent part of it, a part that runs parallel with other R&D activities. In order to allow for this mainstreaming, a reconsideration of the publicity of knowledge (in order to allow for public involvement) will be necessary."* To end with, responders might also consider that public research on risks is important because it is a major concern for public authorities as regulation doesn't oblige industries and laboratories to do so yet.

The focus on risk assessment does not mean that CTs applications have to be abandoned. On the contrary, research on risks can be presented as a prerequisite for uses or something to be undertaken in parallel with technological development : *"risk and conditions of application and uses".* Responders call for a better knowledge of risks without aiming at zero risk : *"classification of toxicity risks", "identification and classification of risks according to the existing results and some new development", "produce a report for evaluation of quantities and potential risks in order to rank the priorities. This report should notably combine the information with other present fields of activity and existing risks and compare them with realistic numbers."*

Seven responders have quoted research on impacts and risks in general: *"Risks", "impact assessment", "danger exploration", "safety", "prioritise further study on basis of risk or potential risks.", "understand potential hazardous mechanisms", "impact of released materials".* Most of the responders have specified that the **risks** are first **sanitary** ones (23 cases) second **environmental ones** (20 cases), without specifying particular technological applications:

- 23 responders have quoted human health concerns: *"impact on health", "human health impacts", "impact on health/Toxiztät", "health issues", "health risks"* (2 cases)*, "human health risk", "impact of techno. on health (…)" , " risk evaluation for health (…) , "health risk evaluation", "permeation into humans", "impacts on human physical well-being above all else", "better knowledge on human health risk to come to a proper risk assessment", "toxicity", " Evaluation of toxicity", "toxicology" (2 cases), "clear tox data to be developed. The main fear is not knowing what is the true risk*.", *"human toxicology", "toxicology (human- (…))".* In this category, 7 responders have focused on workers health, including researchers: *"Protection of workers" "exposure of workers", "Human Health impacts for the workers involved in the fabrication of these materials", "(…) a focus on workers health and "open applications" of nanomaterials", "safe environment for workers (including researchers)".*
- 20 responders have quoted environmental concerns, without specifying a particular technological application: *"environmental consequences", "(…)better knowledge of the environmental effects", "environmental impact", "impact on environment", "impact of techno. on (…) environment", "define possible impact of converging technologies on the environment", "environmental risk", "environmental risks", " risk evaluation for (…) environment", "assessment of environmental risks*

and convergence of technologies.", "environmental risks evaluation and control", "Environmental risks and benefits", "what is the eventual fate of nanostuff released in the environment.(…) " Research on direct and indirect environmental effects of CTs under in vivo/in situ conditions." "toxicology (…) eco-", "ecotoxicology", "Ecotoxicity testing", "ecotoxicology knowledge development", "biodiversity impacts",

A lot of responders have clarified the kind of technological applications to focus on. **Nanoparticles and nano-bio applications** are most frequently quoted.

- Nanotechnology in general and nanomaterials are quoted frequently: *"nanotechnologies and human health", "nanotechnologies and environment", "nanotoxicology, "toxicology of nanotechnology", "health and environmental impacts of synthetic nanomaterials", "Nanotoxicology of engineered nanomaterials", "impact on human health of the dispersion of nanoobjects in the environment", "fate of nanomaterials in environment" "evaluation of the effects of Nano materials on living beings: human/animal, plant", " mobilization of nanomaterials in the ecosystem and dissemination"*
- Nanoparticles in particular are quoted most frequently: *"impact of nanoparticles", "potential hazards of nanoparticles", "effects and interactions by nanoparticles", "Nanoparticles Health", "Health aspects of nanoparticles", "health risks of nanoparticles", " Nanoparticles' impact on human health", "human health impacts of nanoparticles (…)", "Active nanoparticles in human body; in the environment", "possible risk chemical active nanoparticles", "Development of scientific information on (i) the fate and effects of nanoparticles in the environment" "fate and impacts of nanoparticles and nanodevices in the environment", "health effect of nanoparticles in environment", "Nanoparticule absorption by the plants, the ground and the rivers", "Impact of nanoparticles on various health and environmental aspects", "human toxicity and ecotoxicity of nanoparticules", "toxicity of the nanoparticles and the impact in the human health", "human health and environmental impact of nanoparticle-containing devices".* Some responders have specifically focused on cell interactions and toxicity: *"Impact of nanoparticles on cell cultures", "cell toxicity of nanoparticles", "Interactions between nanoparticles and cell membranes." "nanoparticle-cell interactions", "influence of nanoparticles on cell and tissues."* One respondent calls also for research beyond cell toxicity, that is also on alteration of function: *"research on the effect of nanoparticles exposures on living systems (concentrations in different parts of the body, alteration of function (not only toxicity on cells)".*
- Three answers are focusing on non-embedded nanoparticles[8], one focusing on carbon nanotubes and a last one on DNA fragments on nanoparticles *"impact of non embedded nanoparticles", "health effects of free nanoparticles on animals and humans", "free/unbound catalytic nanoparticle hazard", "Impact of nanoparticles, including carbon nanotubes", "DNA fragments on nanoparticles" ??*

8 As shown in part 1, the level of risk decreases from free standing nanoparticles to embedded ones, to nanostructured materials.

- **Nano-bio applications are also quoted**, but much less often than nanoparticles: *"impact of nanobiotech", "human health impacts of (…) nano-bio devices", "hazards of biofunctional devices and materials".* One responder has also quoted heath risks of biotechnologies in general*: "impact of the dissemination of biotechnologies on the environment".*

One can interpret the important concern for nanoparticles risks as a consequence of the precedent of asbestos. For the record, **asbestos** is a kind of ultra fine particles. It represents a clear reference for nanoparticles concerns and *"air pollution*". It is important to note also that nanoparticles is a mature technology and therefore a short term concern : *"short-term: nanoparticle transport, effects on health/environment".* In fact, nanoparticles are already present in our environment, whatever they are natural or man-made. Therefore, four responders have called for using existing nanoparticles as a starting point for further research: *"basic research on the effects of nanoparticles on biological organisms and ways to mitigate negative effects, starting with naturally existing nanoparticles.", "trace of commercially implanted nanoparticles in environment", "Health risks through commercially used nano/biotechnology", "current concentrations of engineered nanoparticles in the environment".* We find again[9] the idea that research on risks should start from already existing potential risks.

To end with, four responders have quoted **personal data protection and political risks** as one of the first two top priority for public research: *"Protection of personal data", "personal data protection", "Applied research on ways to ensure data protection while also allow legitimate use of collected data.", "political risks and privacy protection risks about converging technology".* Four instances is a rather small number. However, part one of this questionnaire has shown that this kind of risk is considered as the highest within the panel of responders (see part 1). Maybe, if responders have been asked to provide 3 priority topics for public research, this kind of risk would have been quoted more frequently.

<u>*Prerequisites of research on risks*</u>

As risks are perceived to be mainly health and environmental ones, responders are calling for research in toxicology and eco-toxicology. Nevertheless, this kind of research appears to depend on other more fundamental research, including methodologies of risk assessment (17.9%) and new technical means (8.8%): ***"ecology",* life cycle analysis, risk assessment itself*,* metrology and classification. All these topics correspond to prerequisites for assessing and managing potential risks of CTs.**

Fundamental science including methodologies

The highest priority (17,9%) is fundamental research about environmental fate and impacts of NBIC devices. Indeed, the difficulty of risk assessment of nano and nano-bio technologies (and their potential harmfulness) relies on the characteristics of theses applications in terms of their ability to **disperse, be**

9 One respondent in the previous question of Part 4 (priority actions) has also quoted: " increase spending on impact assessment, using priorities (particles , eg in cosmetics)"

mobile and persist in the environment: *"mobility", "DISPERSABILITY of the new components and the waste of the industrial processes", "degradation", "robustness and durability of embedment for products", "PERSISTENCE of the new components and the waste from the new industrial processes".* **The persistence** characteristic leads to prioritising research on **long term effects and accumulation**: *" Measurement of long term fate of materials when released to the environment.", "effects of long term exposures to Nano materials: to define accumulation sites in living species (including human) and environment cycling chain, and to point out potential deleterious effects and risks", "Determine the cycling pathways of Nano materials in the environment: waste/emission, air/soils/water transport and accumulations, incorporation in the food chain."*

What is clearly at stake is **the fate of products through their life cycle, especially end of life (waste management)** *"End of life of nano products behaviour.", "toxicology from cradle to tomb products" , "Ecotoxicology and waste treatment", "waste management: recycling", "waste", production/public use/disposal", "waste management of nanoproducts"; "waste and recycling", "waste treatment", "waste disposal and recycleability", "Waste regulation: define in term of regulation how to handle Nano, and how to manage wastes issued from Nano industry", "Support research (notably at industrial processing and waste levels)"*

Accordingly, Life Cycle Analysis appears to be a clear priority for public research: *"Life cycle analyses." "life cycle analysis - to come to sustainable production" "Life cycle analysis", "(a systematic approach on exposure and emission), extended to a lifecycle assessment", "Research designed to produce reliable environmental health and safety data assessing the entire life cycle of the nanotechnology products." "Methods for life cycles analysis of the different nanosized particles and fibres needs to be established" "life cycle assessment", "Understand what happens during the lifetime of the converging technologies"*[10].

As a consequence, research has to tackle complexity and multiplicity of interactions in a systemic approach: *"Environmental Impacts with a systemic approach", "Ecological risk (not risk to individual organisms or species in isolation but to ecosystems and organisms as they exist in actual complex webs of interactions)".* The multiplicity of the players to take in account is a topic research in itself: *"Understanding and simulation of the behaviour of systems consisting of a very large number of components/players", "a clear perception of the hazard including not only possible effect once they interact with the body and environment but also taking the effective mobility of the nanostructured materials in the corresponding matrix into account (hazard assessment).", "analytics",*

Due to these difficulties, research on the risks of CTs implies **research on risk assessment and risk management methodologies :** *"(…) risk management", "applicabilty of risk management methodologies with equal focus on exposure as well as hazard", "adaptation of methods for risk assessment.", "in vitro*

[10] One comment also stated: « economical estimate of the real cost/value of a manufactured and marketed product integrated over its whole life cycle »

and in vivo methodology should be adapted", "experimental planning", " development of adapted risk assessment methodology", "risk assessment (including analytical method design); assessment of risk /benefit relationships (including LCA studies)" **.**

Technical means

Assessing and managing risks implies also being technically able to detect, measure and prevent risks (8,8%). The first step for risk assessment and prevention is **detection** (including inside goods and in their environment): *"Detecting techniques", "Techniques to improve detection.", "Detection of released materials, "methods for detecting the presence of nanotech inside goods", "environmental tracing".* **Detection means traceability**: *"traceability"* (two cases), *" traceability of nanomaterials in the life-chain of products".* **Detection means also metrology**, notably in the air and at workplaces: *" metrology", "How to measure and prevent nano object leak in production process." "governance of new technologies, developing new measuring equipment", "research on methods to determine particles, their sizes, masses and surfaces; development of monitoring devices", "New, better monitoring devices to scan for nanoparticles, especially in the air (i.e. aerosols!)", "Monitoring methods and development of measuring devices which can be used for (…)and monitoring at workplace", "monitoring", "test guidelines for nano chemicals".*

Detection leads also to research on real emissions, exposure and prevention measures: *"emissions", "Exposition (man and environment) » "Improve knowledge of people's exposure" "Exposure assessment", "a systematic approach on exposure and emission, (…)", "development of scientific information on (…) uptake/exposure and health effects of nanoparticles", "means to avoid emission of nano-particles", "limitation of the nanoparticles "spread"" in air from laboratories and industries", "Preventing measures".*

The last, or the first, prerequisite is research on classification: *" definitions and standards" "development of a nomenclature / classification scheme for new nanomaterials"", "standards," "New definitions and test standards needs to be developed"" identify classification schemes (you have to be able to name the objects (i.e. the properties of the objects) you are dealing with and classify them"*

All these research activities are *"Prerequisites for pro-active regulation of nano-risks".* For a few responders, the **scientific bottlenecks of risk assessment and the remaining high level of uncertainty can lead to changes in the risk assessment regulation paradigm by recognising its limits***: "technical means, scientific knowledge: identify the knowns and unknowns in this area", "A recognition of limits on our predictive capabilities, particularly in respect of our growing capacity to reconfigure both organic and inorganic materials at quite fundamental levels."*

Applications

Compared to research on risks (72,6%), a fewer, but still significant, number of answers concern applications of CTs (18,2%).

A first group of comments refers to specific domains of CTs (8,4%), a second one mentions specific environmental applications (9,9%).

Fields of application, nano-bio and nanoparticles:

The nano-bio convergence is the most frequently quoted domain of CTs (11 instances): *"biotechnology", "nanobiotechnology (nanoarrays)", "bio active nanomaterials", " biotechnologies, in particular biochips", "nanodevices and biochips", "nanobiodevices", "Nanobiotechnology", "microbiology", "Microorganisms involvement", "biomedical research & monitoring"? "health".* The second field of application quoted is research on nanoparticules (5 instances): *"free nanoparticles" , "free standing nanoparticles", "free-standing nanoparticles, nanopowders, nanofibers, liquid suspensions", "nanocatalysts, nanoparticles", "research on particules and carbon nanotubes"*

Still, the majority of answers (9,9%) are relating to environmental applications. The general orientation of the questionnaire with the second part specially dedicated to environmental application might explain this result. A non "environmentally-oriented" questionnaire with the same question on priority research topics would certainly have given different results, especially concerning medical applications that are very rarely quoted here: just one case (*"biomedical research & monitoring"* in the previous group of answers "nano-bio convergence field").

Environmental applications:

The general potential of CTs for the environment is quoted three times, especially for reducing environmental impact of industrial processes and transportation: *"how to use the properties of nano materials to reduce environmental impact", "use of nano and information technologies to reduce environmental impact of industrial processes (including transportation)".* Here, new abilities given by the convergence should help design better technologies, *"favour convergence for designing harmless technologies"*.

Some responders have quoted specific environmental applications: energy, monitoring and remediation, especially for water pollution. **The most frequently quoted topic is energy (13 instances), in particular energy production with a clear focus on photovoltaic applications**: *"climate change" (two cases), "energy" (tree cases), "nanomaterials relevant for energy generation", " designing of new products for "green technologies" which are a benefit for society + European Competitiveness (e.g. in the field of energy production [...])", " catalyst", "solar cells and organic electronics in general", "Renewable energies: Solar, energy harvesting", "Improving photovoltaic", "Solar energy nanotechs", "Renewable energies: solar, mobile sources of energy".*

The second topic (8 instances) is monitoring, that can be used for improving knowledge on ecosystems but also for improving the functioning of infrastructures[11]: *"sensors", "development of sensors","[…] monitoring technologies", "Environment monitoring tools", "monitoring methods and development of measuring devices which can be used for environmental monitoring", "ecosystem research & monitoring" "Monitoring of environment and infrastructures", "Environment and infrastructures monitoring".*

Remediation, especially for water but also waste management, is also frequently quoted (6 instances): *"Remediation […] technologies", "Water ", "nanomaterials relevant for water purification", "water treatment; NANO and water is a top research topic for future", " designing of new products for "green technologies" which are a benefit for society + European Competitiveness (e.g. in the field of […) waste/waste-water management)".* Here, the potential of CTs for remediation can be seen as a sufficient reason for taking some, of course, minimized risks,*: "the convergence has to be created by encouraging certain lines of research, accordingly, there are no environmental impacts but only more or less intended environmental effects - if converging technologies are geared toward remediation of environmental problems, I would imagine that undesirable impacts can be limited".* To end with, one responder has also quoted "*artificial nutrition for mankind*" as a priority research topic.

Governance:

A last group of topics quoted by responders (9.1%) is directly related to regulation. One responder quotes *"nutritional awareness",* referring to labelling measures. Two responders quote regulation and control schemes: *"Consideration of how a regulatory framework could be developed"*, **"***governance of new technologies, developing […]control schemes".*

Research on social acceptance and public involvement

10 responders have clearly specified the field of regulation, especially public involvement (2.9%): *"proper governance with public involvement", "public involvement, political will and regulation", "public education/information".* **The political and economical need of public involvement implies some research in socio-economics and ethics**: *"EHS research", "methods to create public involvement in selecting directions", "STS/ELSA-informed research on developing novel solutions to sustainable governance of CTs.", "Social science study to understand the public attitude to this issue", "ELSA project on public needs - what technology does the public want", "Research on the ethical aspects of CTs", "type II research in the sense of Nowotny in order to avoid a complete control of technical progress by ideologists... and media"*

[11] For example, sensors can be used to detect, in real time, leaks on water distribution systems

Education of the public can be education to a non-zero risk society while at the same time risks have to be minimised. In fact, one responder asks "How to change our society from zero *risk tolerance to 'normal' risk acceptance"* just after having specified *"Toxicology of nanotechnology*" as the first priority.

Research on utility and goals:

5,1% of the responders have insisted on the fact that the **progress generated by converging technologies but also technology in general should not be taken for granted**. **Technical progress depends on the utility of the technologies developed**, especially to solve environmental problems. Still, defining what is an environmental problem and which ones should be challenged is also at stake: *"Environmental endpoints (deciding through broad participative and deliberative processes what it is exactly that we wish to protect when we wish to protect 'the environment')".* Therefore, the first step is to **have a clear view of the benefits** of these new technologies. *"define which areas are relevant", "mapping of potential added value of nanomaterials as a part of the solution to environmental challenges (p.e. energy, particle emissions, doing more with less through better protection, ... etc.)".* This implies to validate the performances, the "e*ffectiveness*" of these technologies and their harmlessness, which can imply to focus on the reversibility of risks or on the application of the precautionary principle if this reversibility is uncertain: *"reversibility; Converging Technologies and the precaution principle".* Two responders have also specified that the benefits should not be restricted to developed countries but have to include the whole world: *"research for beneficial applications, including for developing countries", "have a clear view for mankind".*

The second step is to **compare the new converging technologies solutions to other not necessarily new technologies**(*comparison with ""old"" methods*"), **or non-technological solutions***: "alternatives for nano"*. Here, the technological nature of solutions is questioned, especially in comparison with institutional solutions. *"A top priority is to develop a methodology to define appropriate portfolios of technological and institutional approaches that are most suitable to deal with actual environmental problems. So, one should not start with the premise that converging technologies are most appropriate; one should start with the question, given actual environmental problems, which mix of technological and institutional/societal approaches is most likely to solve actual environmental problems."* From that point of view, technology is not the only solution or even a solution. "*This questionnaire is focused in a manner that, Nanos in particular, the Technology in general, are the unique response to challenges Humanity has to face. The unique possibility let to the public is to try to obtain regulations in order to limit possible damages. No way to question the Technology and ask for evaluation of possible alternative approaches, knowing that, often, the solution is not a matter of technology."*