

Nano-Conceptions: A Sociological Insight of Nanotechnology Conceptions¹

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Summary

This report, which comprises the conceptions of diverse actors involved in nanotechnology issues, is a product of the *Nano-Conceptions survey* carried out on April 2006.

It aims to provide reliable and first-hand data relating to conceptions held by certain key 'stakeholders' concerning the development process of nanotechnology and its potential social and ethical gaps and implications. Hence, in order to 'map' the sociological context in which nanotechnology development is embedded, the Report was envisaged as a 'constructed dialogue' on the diversity and similarities of points of views and beliefs of the contributors.

As an analytical tool, it does not seek to embrace a 'pro' or 'anti' nanotechnology position *per se*. Believing that such types of contributions are necessary and useful for the enrichment of the language, knowledge and understanding within a group of actors that feel a kinship with each other (to some degree or another) but which are not necessarily helpful for establishing a dialogue between the diverse communities of actors, the Report presents the conceptions 'as they are', leaving the reader to form her/his own interpretations and opinions.

The main issues assessed by the Report are: the development pace of nanoscience and nanotechnology; the constraints, gaps, quality and certainty of nanoscientific and nanotechnology knowledge; the concerns relating to potential and plausible social, ethical and environmental impacts; the aspects of military defense and security nanotechnology applications; the relationship between nanotechnology and the solution of practical problems in underdeveloped countries; and the communication proposals among actors and communities for policymaking.

Finally the Report comes with a draft proposal titled: A Dialogue Methodology for Policy of Nanotechnology Implications, which could be extended to Converging Technologies Implications, and other related areas.

This report is expected to contribute to a wider public understanding of nanosciences and nanotechnologies implications while at the same time proposing some steps to take in order to move the dialogue and debate forward.

Introduction

The report is a product of a survey among diverse actors involved in nanotechnology issues. Most of them are what we in general tend subjectively to categorize as *experts*.

The range of 'expertise' has included politicians, scientists, businessmen, and journalists. The *general public* has been considered but as a 'barometer' of the social awareness of nanotechnology implications.

For methodological and practical purposes, and owing to funding limitations, the *Nano-Conceptions* survey was implemented via the Internet through email contact of around 1,500 experts mostly from Europe, the United States and Japan. A low percentage replied to the survey (89) and even fewer participated (51). Despite this, it can be said that the quality of the responses from the participants makes the surveys' sample a good one but, certainly, in any case a sufficient one.

Yet, considering the limited spectrum of the survey, this first approach seems to be a very useful instrument for an introductory and general appraisal of the sociological nature of the *nano communities* and the diverse groups that can be classified as being in a dialogue methodology for policymaking. These, in broad terms, are:

- Natural Sciences Community
- Social Sciences Community
- Government Community
- Private Sector Community
- And, Society

Every nano-community (as seen in this report) has an extensive number of '*clusters*', fields or disciplines (e.g. Chemistry, Physics; Sociology, Philosophy, Economics; NGOs, Mass media, etc) that are successively shaped by several 'sub-clusters', schools of thought or particular groups that 'feel' a kinship with each other. Such sub-clusters as representatives of particular conceptions and interests might differ considerably with each other and may or may not be carriers, in some degree or another, of hype.

For example, in the case of nanotechnology's interpretation, on the one hand, there is, in broad terms, the *mainstream nanotechnology* cluster (or the materials science type of nanotechnology); and, on the other hand, there is the *molecular manufacturing nanotechnology* school of thought (Drexler's type). The last one is often identified as a pseudoscience or science fiction even though its unfeasibility has not yet been scientifically demonstrated (it is well known that quite a number of scientists –such as Smalley³- consider that there are severe technical and maybe physical restrictions).

It is important to clarify that in order to avoid any misunderstandings, the term of 'stakeholders' is not used in the report (unless it is in quotes). This is because, strictly speaking, such a conceptualization might limit the number of actors to be included since

a 'stakeholder' must have a 'stake'-in, and therefore a 'legitimate' interest. Hence, it is a connotation that from a sociological and ethical perspective, leads us to formulate questions such as: Who is a 'legitimate actor', and who is not, and to what degree (if any)? What are the parameters that define and measure it?

Instead, as described above, the report will refer to 'communities' and its 'clusters' and 'sub-clusters' since they seem to be more suitable for our purpose because they can potentially take into account everyone, including those who do not have a direct stake; those that might be impacted by, and; those that have the right to take a position even though they might not be (directly) affected.

Taking into account this conceptual clarification, and in order to 'map' the sociological context in which nanotechnology development is embedded, the report has been conceived as a 'constructed dialogue' and hence built-up on the diversity and similarities of the points of views and beliefs of the contributors to the *Nano-Conceptions* survey.⁴

How the conceptions and particular interests of each sub-cluster and cluster are transforming; how they 'model' the advancement and the characteristics of nanoscience and nanotechnology in one or another direction; and what the implications are of this (e.g. the institutionalization of conceptions and interests, etc), are aspects beyond the scope of this Report even though it is evident that these are key issues which need to be studied using a profound and detailed sociopolitical insight of nanotechnology development and its implications.

Instead, the explanatory purpose is quite limited. The idea is to offer, in one exercise, some of the main conceptions that are circulating among the 'experts' and that mainly dominate the 'nano debate'. It is evident that the conceptions presented "are very general first comments" and, as pointed out by Dr. Maj M. Andersen of the RisØ National Laboratory (Denmark), "...in all, there is not much new coming out."

The Report should thus be seen as an exercise to grasp the range and variety of general nano-conceptions as such and as a way of recognizing the process in which these are usually being disseminated from the 'experts' arena and into the public sphere in general.

The main issues assessed are:

- Stages of Nanoscience and Nanotechnology Development
- Constraints, Gaps, Quality and Certainty of Nanoscientific and Nanotechnology Knowledge
- Concerns relating to Potential and Plausible Environmental, Ethical and Societal Impacts
- Aspects of Military Defense and Security Nanotechnology Applications
- Nanotechnology, Practical Problems and 'Underdeveloped' Countries
- Communication Proposals Among Actors and Communities for Policy Making

Therefore, the Report can be seen as a raw material source for a wider discussion and evaluation of the aspects and dimensions of the development of nanotechnology just mentioned –and the like; and not as an evaluation *per se*.

However, the discussion and evaluation have to be considered as a relevant ‘must’ not only because the lack of dialogue is costly, but also because in the very near future we will have to face, not only the (nano)technological ‘context of justification’, and the ‘context of application’, but the ‘context of implications’ as well.⁵

An evaluation effort based on the establishment of a real, serious and active dialogue seems to be an unavoidable necessity since the public acceptance of novel technology in general is no longer a trivial thing; rather it is a prerequisite for the successful implementation of technology.⁶ In this regard, the main worries are related to the kind of nanotechnology that society needs; and to questions concerning by whom and by which instruments these areas are being developed and regulated. This means that future consequences of nanotechnology (and indeed of *converging technologies*) are increasingly becoming relevant. Key issues include the ‘distribution of risk’, as well as economical and political justice and power affairs within international, regional and national spheres.

A major reflection should then be made because, “...scientific and technological innovation has the fundamental characteristic of being unpredictable in the sense that the results are in principle unknown until they are found.”⁷

If nanotechnology is considered to be a powerfully transformative technology, then “...it is critical to understand where this technology is coming from and where it is going”.⁸ Analytical clarity is crucial in order to advise policy makers properly. Presently there is widespread confusion between the reality of nanotechnologies (in the short term), their potential (in the medium and long term) and the ‘stuff’ of science fiction, and not only on the part of the general public.⁹ Similarly, there seems to be some naïve suppositions ‘out there’ regarding certain social and ethical aspects of nanotechnology, specially a naïve assumption of a context of power-relations emptiness and therefore of class conflicts.

Hence, this report on a *Sociological Insight of Nanotechnology Conceptions* expects to contribute with the current debate while clarifying some delusions and at the same time by taking the dialogue forward by proposing ‘A Dialogue Methodology for Policy of Nanotechnology Implications.’¹⁰

Finally, it is important to state that this report does not intend to take a ‘pro’ or ‘anti’ nanotechnology position *per se*.¹¹ Believing that such types of contributions are necessary and useful for the enrichment of the language, knowledge and understanding within a cluster or in similar clusters, as well as for sociopolitical activism, yet that they are not necessarily helpful for establishing a dialogue between the diverse communities and actors, the report presents the conceptions ‘as they are’, letting the reader to form his/her own interpretations and opinions.

However, this does not mean that the way this text has been configured is completely free of the author's values and conceptions.

Stages of Nanoscience & Nanotechnology Development

There is as much difference between nanoscience and nanotechnology as there are among concepts and reality; asserts Prof. Olivier Vanbésien, director of the CNRS research group on Nanoelectronics at the University of Sciences and Technologies of Lille (France). In other words, he clarifies: "...[on the first level] the imagination allow us to conceive all the types of nanoobjects, the potential applications of those nanoobjects in domains equally variable such as medicine, biology or telecommunications...on the second level, researchers envision the fabrication and identify the technological locks to be overcome for the 'real' fabrication of objects. The time needed to go from the concepts to the reality is very difficult to quantify."

Hence, at this early stage, Dr. Patrick Lin research director of The Nanoethics Group (US), suggests that both nanoscience and nanotechnology seem to be closely related, so much of that current research appears to fall into both categories. He then adds: "...there is definitely a sense that nanotechnology will be a lucrative market, so naturally there is a strong focus on productizing or finding practical applications for nanotech. However, because so much of nanotechnology depends on nanoscience (where revenue streams are less clear, longer term, and mired in IP issues), the limiting factor may be how quickly researchers, mostly in academic centers, can develop the basic science –which in turn is partly limited by funding." For instance Clive Ireland, founder of Advanced Optical Technology Ltd (UK), deems that nanotechnology "...is a fashionable area [yet] driven by academic/institutes R&D and probably too much government money." The incongruity is that nanotechnology R&D usually requires costly infrastructure that cannot be afforded by small and medium sized enterprises (at least in most cases of leading R&D).

Besides, the nanotechnology market is still dominated by luxury goods, as asserted by some 'experts', although this is a tendency that is expected to change. Dr. David Berube from the University of South Carolina, communications director at the International Council on Nanotechnology (US) and author of *Nano-Hype: The Truth Behind The Nanotechnology Buzz*, believes that, "...this will change soon as new materials in defense and energy begin to emerge, and within a few years, in medical applications as well."

The general concurrence is that nanoscience is ahead of nanotechnology, yet conversely there are big disparities on what everyone means with each particular concept. This has been the main dilemma identified when trying to outline the pace of nanoscience and nanotechnology R&D, which brought out two interesting aspects:

a) *The size feature (below 100 nanometers) has not resolved the 'overlapping' conflict between old disciplines and new ones.*

For example there are some observations that nanochemistry is simply chemistry (or supramolecular chemistry) –namely the chemistry of atoms and molecules; nonetheless, for Dr. Geoffrey Ozin from the University of Toronto (Canada) and co-author with André Arsenault of the book *Nanochemistry: A Chemical Approach to Nanomaterials*, this is not quite correct and it is an issue worthy of further debate. When asked about what makes nanochemistry 'nano', he stated that, "...nanochemistry is the Chemistry of diverse kinds of nanoscale building blocks [...which] are much larger than atoms and molecules, and span fully the three orders of magnitude between nanometers and micrometers, which by definition encompass the nanoscale size range. In fact, the building blocks of Nanochemistry may not even be molecular - they can be fashioned from nanoscale pieces of metals, semiconductors and insulators, or made of nanoscale macromolecules and bio-molecules." Thus, a more precise definition of nanochemistry, he concludes, might be, "...a chemical approach to nanomaterials".

A similar dispute was registered in the early 1990's, as recalled by Dr. Roger Strand, director of the Center for the Studies of the Sciences and the Humanities at the University of Bergen (Norway), with the case of molecular biology and functional genomics.

One successful transformation –or at least more subtle- is the one experimented by the field of photonics, lately renamed as 'nanophotonics'. As stated by Dr. Aasmund Sudbø from the University of Oslo and the University Graduate Center at Kjeller (Norway), "...nanophotonics, both science and technology, became mainstream photonics long before the term was invented and the development pace has been steady and reasonably predictable".

Such co-existence of what I call 'mother' and '(nano)child' disciplines or, in the words of Prof. Mark Welland of the Nanoscience Centre, University of Cambridge (UK), the "weakness at the boundaries between established disciplines", has taken philosopher Ashely Shew of the Virginia Tech in Blacksburg (US) to inquire "...whether there is such a thing as nanoscientific/technological knowledge, or whether there is knowledge from a few disciplines about the same scale."

It is an interesting viewpoint that perhaps is better comprehended when nanotechnology is seen not as a "single technology" but as the leading technological niche that pushes ahead "...the transformation of the 'technology as a whole' by subjecting almost every field to techniques of molecular analysis, characterization and manipulation"; says Niels Boeing of *BitFaction* (Germany). From that perspective, Boeing guesses that, "...in 30 years the term of nanotechnology will be superfluous because it has become evident that some molecular process is involved".

Thus, it could be stated that nanotechnology and the rest of the so-called *converging technologies* (either the US' NBIC, the European's CTs, or other versions)¹² are an

outcome of the type and inherent logic of modern technology development as a whole rather than a mere natural and spontaneous process of convergence.

b) *The divergence of nanotechnology operative perspectives beyond the top-down and bottom-up approaches is a permanent compelling disagreement between the 'mainstream nanotechnology cluster' and the one of 'molecular manufacturing nanotechnology'.*

Thus, in order to avoid the escalation of public misapprehension and refusal of nanotechnology as a whole (as well as avoiding the hype) the conflict has been temporarily 'resolved' (either deliberately or unconsciously) by a couple of mechanisms. One method is by categorizing molecular manufacture nanotechnology as an impossible quest and therefore as science fiction (at least until it may prove 'itself' to be a real possibility). And, on the other hand, and particularly in the United States, by consistently clarifying the existence of at least two types of nanotechnologies.

In this regard, Ashley Shew observes that, "...nanoscience and nanotechnology development differ depending on the specialty and context and what you count as nanotechnology...there is more than one nanotechnology right now. Drexler and his associates seem to be talking past the scientific nanotechnological community much of the time because their concerns are about a different type of nanotechnology than that which Smalley and other address. The concerns stemming from these two understandings are very different."

Constraints, Gaps, Quality and Certainty of Nanoscientific and Nanotechnology Knowledge

The Constraints

"...A condition imposed on a system which limits the freedom of the system; may be physical or mathematical, necessary or incidental."

McGraw-Hill's Dictionary of Scientific and Technical Terms.

Imagining a nanometer is easier when it is compared with other objects such as cells (relative measures) but it becomes nearly impossible when one tries to do it in absolute terms. In fact scientists do not 'see' atoms with their naked eyes. Instead they 'define' atoms' shapes and their arrangements by using electron beams, in addition, the details can only be visualized indirectly (in the best case). However, for Dr. Jürgen Altmann of the Experimentelle Physik III at Dortmund (Germany), "...visualizing atoms is easy nowadays with various atomic-probe microscopes which use either a current or forces."

Yet with regard to subatomic particles the issue does not seem as simple. For that reason Dr. Sudbø with 20 year of experience on the field, is aware that "...the central gap in nanophotonics is precisely the quest for nanometer resolution in optical lithography." But, on the contrary Dr. Altmann remarks that, "...the lithography gap

mentioned by Dr. Sudbø is not directly related to this [visualizing at a nanometer resolution] –it is about structuring masks, etc., at tens of nanometers (nm) whereas atoms (with tenths of nm) can already be seen by other methods.”

Dr. Sudbø replies by stating that considering that, “...every scientific community [or cluster and sub-cluster] has its own definition of nanoscience and nanotechnology...the central gap in nanophotonics...at the same time, it is one of the most serious potential showstoppers for the microelectronics industry today, and [thus] there is an international army of scientists and engineers working very hard to close it.”

Besides the differences (and also because of them) the constraints seem to be clearly there –either of technical and/or methodological nature. That explains in part why there are major efforts being carried out for the improvement of such a details’ visualization by extending the range of X-rays; for example at the Linac Coherent Light Source (Stanford Accelerator Center) in California (US) or the German Electron Synchrotron research center in Hamburg (Germany).¹³

Hence, it can be said that scientists are limited to experience and manipulate the nanoworld through instruments that make things look bigger/different. “Nanoobjects cannot be handled directly by hand, an intermediate tool is needed to do it”, says Didier Theron of the CNRS – Institut d’Electronique de Microélectronique et de Nanotechnologie (France). And he adds: “...the development of such tools is part of the research process”.

So, if we take into account that it is well known that for instruments like the *Scanning Tunneling Microscopy* (STM), both external and internal vibration are a problem¹⁴, then we could say that there is a fundamental constraint on nanoscience and nanotechnology knowledge as “...it is clear that the set of quantitative readings taken by the experimental apparatus cannot be considered independently of the interpretation put on them...Although tools are auxiliary to the advancement of scientific knowledge, their influence on the directions of work done is important and frequently decisive.”¹⁵ This does not mean that the nano-instrumentation is useless, on the contrary; it just denotes that the readings, and thus the results, are highly dependent on the interpretation and on the effective worthlessness of the error factor caused by externalities such as vibration (an externality that for Dr. Altmann can be handled quite well).

Hitherto, the high degree of complexity and uncertainty that govern the world at the nanoscale level both in time and space (namely the principles of quantum physics), nanoscience and nanotechnology constraints are being identified by many members of the scientific community as being no different from any other.

The Gaps

Contrary to other cases, says Prof. Arturo López-Quintela of the Department of Physical Chemistry at the University of Santiago de Compostela (Spain), “...the theoretical

background, which usually is assumed to be known, in this case is different, and many properties of the materials at this level are practically unknown and therefore not always predictable.”

Nevertheless, it is a lack of knowledge that is commonly surpassed by technical knowledge gaps. Dr. Vanbésien estimates that, “...technological locks are mainly of technical type because in general terms the theoretical problems are solved before the technological lock.” Of course, he adds, “...there are exceptions such as quantum informatics where researchers propose objects that might support quantum calculations while theorists are still discussing the viability of certain concepts”.

Considering the presence of both types of gaps, common in all S&T fields, even though in different proportions (and variable for each discipline), Dr. Ramón Compañó of the Institute for Prospective Technological Studies (DG Joint Research Centre - European Commission) indicates, for example, that adequate modeling at the meso-scale is a notorious theoretical gap, while the need of high throughput instrumentation and mass scale devices are illustrations of experimental gaps.

Others, as seen by Dr. Theron, are a result of the fact that handling nanoobjects is difficult and requires new instrumentation tools yet to be developed; that the nanoobjects handle nano signals; that parasitics coming from the environment must be carefully controlled; and that the connection of nanoobjects to the outside world [at the macro level] has not been resolved.

That last gap has been a point of concurrence for most of the experts, particularly those from the natural science community or those who are actually manipulating matter. This is supposed to be relevant because, as Dr. Juan Carlos Rodríguez-Cabello of the Mineralogy, Crystallography and Condensed Matter Physics Department – University of Valladolid (Spain) says: “...self-assembling must play a decisive role in the future nanotechnology and still a lot of effort must be applied to understand the basis of this phenomenon and its rationalization.” The gap is of major order and it is in some way recognized by Dr. Rodríguez-Cabello himself: “...as a specialist in soft nanotechnology, I would say that our ability to produce highly functional molecules with potential to trigger a hierarchical organization through different length scales is not enough today. We need to synthesize extremely complex and well-defined (macro)molecules that in most cases are well beyond the reach of conventional chemistry even by advanced chemistry.”

Niels Boeing, who has been paying attention to the issue and talking with experts, believes that, “...at the moment there seems to be no clear path how to complement self-assembly by a new artificial integration mechanisms [until now it has been dealing with bio/chemistry self-assembly]. Even in DNA scaffold construction a lot of auxiliary chemistry is involved and the process is not very precise (based on what experts like Dr. Ned Seeman told me).” And makes clear: “...I would not dare to say that overcoming the integration problem is not feasible. However, I personally doubt whether the concept of molecular [manufacturing] nanotechnology as proposed by Drexler,

Merkle, Freitas *et al* can ever be put into practice due the chicken-egg-problem that you need an assembler to build the first assembler. I don't believe that it can be done in a step process as suggested by Freitas in a reasonable time span."

That which is mentioned above is more a debate on "...all those things which one would wish to have but have not yet been achieved", as it is accurately set by Dr. Altmann (Germany) who adds: "...one glaring gap is the failure of the mainstream scientific community to scientifically analyze the feasibility of 'molecular [manufacturing] nanotechnology'." A context in which of course, molecular nanotechnology discussion is somewhat different from the gap discussion, as Dr. Altmann further clarifies.

From the aforementioned, it can then be said that along with the gap in the definition of the actual 'point' where properties change relative to size, the connection between the nano/micro and macro worlds probably emerges as "the" major gap.

Moreover, other additional gaps quite different in nature but no less important are those related to the unknown effects upon human health and the environment. In other words, a lack of knowledge of all those 'things' that the scientist community should/must seriously close the gap on, within the shortest possible time, in order to avoid unnecessary risks.

For Dr. Paulo Martins from the Institute of Technological Research (Brazil), it is a circumstance in which, "...there are theoretical problems related to the 'construction of a new nature' in the sense that we are placing into the environment structures that do not exist in the natural ecosystems while we lack of a theoretical approach to take into account the complexity of the issue."

Nora Savage, an environmental engineer at the Environmental Protection Agency (US) acknowledges that: "...compounds for which we have toxicological, fate/transport, or bioaccumulation/bioavailability data may have to be reassessed due to the fact that at the nanoscale, chemical and physical properties are often drastically altered [...] We are just at the beginning of our knowledge base in this field...we are learning that: 1) these materials need to be well characterized and standardized so that research results can be compared; 2) using engineered nanomaterials may not be as appropriate as examining the consumer products in which they are incorporated; and 3) it is not enough to state that engineered nanomaterials embedded or fixed in a matrix poses no environmental or human hazard –the end of the product needs to be considered, if the product is burned, placed in a landfill with reactive liquids and gases, recycled, etcetera."

On the other side of the Atlantic, Dr. Altmann agrees: "...Concerning fates and effects of nanoparticles in the body and the environment, there is an obvious (and generally acknowledge) lack of acknowledged; all the more remarkable is the fact that nanoparticles are being put into consumer products relying just on the licensing for the material, even though every overview article states that: 1) at the nanoscale matter

shows different properties; and, 2) nanoparticles can enter through pores where larger ones cannot.”

Kathy Jo Wetter from ETC Group (Canada), one of the most active actors of the society community, coincides by arguing that “...nanoscience and nanotechnology are developing in a regulatory vacuum and therefore any pace of its development is inappropriate until best practices (for nanoscience) and government regulations (on the products of nanotechnology) are put in place [...As] science and technology must be guided by the Precautionary Principle [...] scientists and regulators should be able to quickly establish safety standards and mechanisms for monitoring and then the development of nanoscience and nanotechnology could continue.” Thus, says Dr. Wetter, it is urgent that we fill the gaps in, “...the understanding of toxicology of nanoparticles in both the short and long-term, and the standardization measurement and nomenclature of nanoparticles.”

From the social community, Dr. Berube describes what he perceives as quasi-scientific gaps. For example, he writes, “...unless we can get a handle on classification and nomenclature the regulatory dynamics of all things nano will be especially challenging. The other gaps have to do with markets and consumer willingness to buy into nano; especially when the first products will carry a research surcharge of sorts and will be more expensive than competing products [...] It is interesting to ponder how that phenomenon might impact the development of new technologies.” Expressed in a differently, “...there are technological and economical difficulties to move the fabrication processes of nanosystems from the lab to industry”, says Prof. Juan Irache from the University of Navarra (Spain).

The concern is mutual for Dr. Bikram Lamba director of Toronto Management Consultants - Tormacon Limited (Canada). He declares that: “...the gaps are essentially between commercial exploitation of technology. All development is basically at the lab level. There is need to upgrade it to commercial level, to have all benefits [...] Organizations like Tormacon can help identify appropriate commercial partners [...] and be used as a coordinating agency.”

From a different perspective, Dr. Guillermo Foladori of the University of Zacatecas (Mexico) and member of the *International Nanotechnology and Society Network* senses that, “...following the technical characteristics it will probably be the industrial revolution with the most uncertainties and unknown outcomes in human history. The main gap is a reduced interest or a lack of public funding in following scientific and technical advances with philosophical, political and social discussion.”

The Quality and Certainty

Dr. Theron (France) seems to be cautious about the quality and certainty of nanoscience and nanotechnology knowledge when calling the attention to the well-known possibility that, “...competition for industrial achievement increases the risk of cheating.” Still, he believes that the quality and certainty of nanoscience and

nanotechnology knowledge do not have *a priori* difference with other fields of science. It is just new and not mature enough, he says.

Additionally, the reality of upcoming risky and unnecessary situations is recognized mainly because of the *rush* and lack of caution on the part of some actors from the private sector community when “trying to capture the market value of nano” while ultimately affecting the public conception of the quality and certainty of nanoscience and nanotechnology knowledge and thus of nanotechnology as a whole. That seems to be true in the case of Kleinmann household cleaning spray.¹⁶

Unfortunately, asserts Dr. Berube, “...the Kleinmann magic nano product produced some bad press for the industry. Given we still do not know whether nanoparticles were in the aerosol and Kleinmann seemed unaware of the Environmental Health and Safety (EHS) research done on the components of its own product and the seal of approval seemed to have been used improperly, we must consider that some companies may be acting in haste to capture the market value of nano without full consideration of EHS implications and that is a real problem.”

On the same train of thought, Prof. Welland (University of Cambridge) declares: “...In the headlong rush to capitalize on both nanoscience and nanotechnology quality and scientific rigour is certainly suffering.”

Thus, in the modern S&T history the *time* variable once again proves to be a key component –among others of technical and sociopolitical nature- that affects the quality and certainty, in this case, of nanoscience and nanotechnology knowledge and consequently of the public confidence in nanotechnology innovations.

How can the quality of S&T knowledge be ‘protected’ from variables different than those of a scientific and technical nature?

Concerns related to Potential and Plausible Environmental, Ethical and Societal Impacts

Most applications have and will have some kind of impacts; otherwise, states Dr. Lin (Nanoethics Group, US), what’s the point of creating them?

Accordingly, many of these potential social, ethical and environmental impacts (good, bad and/or ambiguous) have been *addressed* by reports from the government community¹⁷, insurance companies¹⁸, NGO¹⁹, and other entities.²⁰

It is a context in which for Dr. Lin, “...even the simple nanotechnology products today (such as using nanomaterials in golf balls or cosmetics) raise manufacturing and consumer safety issues, in addition to environmental concerns [...Yet] in the near future, the impact will shift more to societal and ethical areas, such as privacy from

virtually invisible surveillance devices or new treatments that change how we view medicine.”

And certainly, the environmental aspect of nanomaterials is an issue that has taken (for the moment) the center-stage or, in other words, it is the one that has been broadly discussed.

For instance, along with the previously mentioned words of environmental engineer Savage from the EPA (US), Dr. Kayori Shimada from the National Metrology Institute of Japan (part of the National Institute of Advanced Industrial Science and Technology) adds that a potential concern is “...the trapping technology of nanoparticles. Nanoparticles in the air are sometimes dangerous but the trapping of nanoparticles is enable by nanotechnology.”

Also, Dr. Berube (USC, US) states: “...we need life cycle studies, especially with disposal and incineration. We need comparative risk assessments since nanoparticles with some drawbacks might be a lot better that what we are currently using, and we need a better understanding about whether green nano is as green as it is touted to be.”

Such ‘*green-hype*’ of nanotechnology, as I call it, is an issue that in fact Volker Türk, project coordinator at the Sustainable Production and Consumption Department of the Wuppertal Institute for Climate, Energy and Environment (Germany), reasonably queries on the following terms: “...Many argue that nano-application will help to increase resource efficiency but this is not necessarily the case. Resources are the backbone of every economy. In using resources and transforming them, products are produced, infrastructures built up and values created [...] Small does not necessarily mean little resource use, in particular as long as we use top-down technologies, in which bulk materials are processed down to the nano-level. One must consider the entire life cycle to assess the resource efficiency, including the use phase. If nanomaterials are used to produce catalytic materials or surfaces, then those might be more resource intensive to produce and we might not be able to re-capture those particles in the disposal phase, but these nanomaterials might help to reduce the energy and resource use for various processes in their use phase. So only if you look at it along the life-cycle, comparing in this case the resource intensity in the production phase with the potential resource savings in the use phase, one will be able to judge on the overall potential.” And he concludes: “...[already] first studies on nanotech applications show that these are not necessarily contributing to an increased resource efficiency. In particular the use of high-processed materials and precious metals is an issue that should be look at.”

For instance, I believe that evaluations from an *Ecological Economics* and an *Industrial Ecology* perspective, and the like, could be very useful as they could take into account the (nano)materials and energy flows, as well as the waste and recycle processes (see Image 1).²¹

Furthermore, other aspects remarked by the majority of participants of the *Nano Conceptions* survey can be summarized as follows: health risks for workers during new production processes; introduction of free nanoparticles into the environment and as a route for human exposure along with a largely inadequate response from Governments to commission toxicology studies; environmental problems from large-scale production; difficult-to-recycle nanocomposites; ethical aspects pertaining point-of-care medical diagnostics, treatments and implants; new products that change the face of industry; glutted markets, upheaval of the global financial/manufacturing system; significantly reduced employment opportunities for less skilled labor, unequal distribution of benefits and wealth (e.g., in medicine), 'nano divide', equity disputes about intellectual property rights, conflicts of interest in university–industry relations; invisible intelligence gathering devices, covert activities; invasion of privacy and of the human body without the individual's consent; security and safety of persons; super intelligent, virtually invisible devices from nanotechnology combined with artificial intelligence; nanoweapons, artificial viruses and bacteria, controlled biological and nerve agents; etc.²²

Among the long-term-vision-implications, Dr. Vanbésien (France) says that, "...the ultra-positive aspects are the medicine and healthcare applications which are going to benefit greatly with the development of the nanosciences and nanotechnologies. In a more ambiguous way, the 'manipulation' of the intrinsic properties of matter (genetic applications) remains as a major open-problem that will need a long and extensive debate between specialists and non-specialists."

Even so, Dr. López-Quintana (Spain) believes that, "...from a scientific point of view there is a *priori* no difference between nanotechnology and technology [...since] All of them nano and micro/macro technologies have similar impacts." Dr. Lamba (Tormacon Ltd) seems to agree by saying that "...there is no evidence of such parameters [social, ethical and environmental implications] affecting nanotech research." As well does Dr. David Parker, director of Parker Consultancy Ltd (UK) also believes that nanotechnology, "...is just another technology and should be treated no differently than other technological areas."

Likewise, Dr. Michael Veith from the Leibniz Institute for New Materials (Germany) considers that in fact, "...nanotechnology will have an impact on our life, but perhaps less dramatically as it is usually thought"; whilst Dr. Irache (Spain) still feels that, "...the potential could be immense but it is just a potential. Nowadays there is practically nothing."

Even more far-reaching, Dr. Rodríguez-Cabello (University of Valladolid) has sustained that: "...there is no real negative ethical or environmental impacts. On the contrary, nanotechnology will bring important and deep environmental and social advances."

Instead, Savage (EPA, US) considers that "...it is too early, and hence unwise, to make such predictions [on nanotechnology implications] until our knowledge base has greatly increased."

On this same track, some experts have considered that nanotechnology-related concerns are over-rated especially when the time to the market in most cases will be rather long. Others, in what appears to be a discrepant position, have indicated when speculating on the reasons for the lack of dialogue and measures-taken (related to such concerns) that, if we're talking about business, the discussion of these issues may scare off investors as well as cause more regulation to be enacted, which is a barrier to the corporate goal of selling more products in the marketplace.

Dr. Foladori, editor with Noela Invernizzi of the book *Disruptive Nanotechnologies – The Social Impacts of Nanotechnologies*, disagrees. He believes that only the impacts that can be observed immediately will be avoided, probably on environmental and health risks. In social and economics impacts nothing will be done, he adds, since: "...a) nanotechnology is seen as a panacea for meliorate competitiveness, and this is considered good by itself; b) as business and scientific groups see nanotechnology as a road to improve their position, the philosophy is 'it is too early to discuss about implications...we better wait till things are consolidated'. This position avoids public concern and participation, as well as new incomers bargaining for research."

Dr. Wetter (ETC Group) also thinks that there are some serious social and ethical impacts that have yet to be considered. And exemplifies: "...the impacts and ethics of patenting the fundamental building blocks of nature, the impacts of new nanomaterials on conventional commodity markets (and on the economies of commodity dependent developing countries), the impacts of 'enhancement' technologies on the rights of the disabled and the potential impacts of nano-scale technologies on democracy and dissent."

It is important to note that independently of the differing positions and the notorious mixture of aspects of the previously mentioned concerns, is the degree to which the potentiality of nanotechnology is revealed while forcing us to identify the diverse levels of implications not only of nanotechnology as a whole but of the applications of nanotechnology in particular. Biochemist Dr. Gregor Wolbring of the University of Calgary (Canada) seems to concur as he thinks that, "...every nano application leads to different concerns with different impacts and different regulations. Most products are not discussed in general and in particular settings."

Boeing advocates that in order to confront this complexity, "...we should implement [as a starting point] a classification into 1. contained nanotechnology, 2. a) non-intentionally bioactive and b) intentionally bioactive nanotechnology, and 3. disruptive nanotechnologies" (where he puts molecular nanotechnology meaning autonomous nano-agents like assemblers or artificial viruses/bacteria). He then adds, "...at least the last should be banned [referring to artificial virus/bacteria]".

Additionally, thinking on molecular manufacturing nanotechnology feasibility, Mike Treder, executive director of the Center for Responsible Nanotechnology (US) has declared: "...It is urgent to understand numerous issues –environmental, economic, military, geopolitical, humanitarian, social and technologically related to an advanced

form of nanotechnology, molecular manufacturing- to prepare for its likely development sometime in the near future...This technology could develop too rapidly for reactive policy to succeed...it will be more powerful than most people will be able to comprehend without serious study. Molecular manufacturing, along with other technologies that it will enhance or enable, will create new problems and new opportunities that require new solutions. To date, there has not been anything approaching an adequate study of these issues. Today the pace of technical advancement is far ahead of studying and preparing for societal and environmental impacts of technology. Unless this balance is corrected, we will enter the future unable to effectively and responsibly manage the tremendous power being unleashed by nanotechnology. We may have only one chance to get it right.”

Aspects of Military Defense and Security Nanotechnologies Applications

Questions relating to the use of nanotechnology for the purposes of military defense and security were fairly extensive. Only a few actors from the corporate and policymakers' clusters explicitly evaded putting forth their position publicly, while not a single reply from the military and security research agencies' cluster was received (among more than a hundred).

It is an issue of public concern usually plagued of a peculiar (but militarily understandable) secrecy which most of the time shields it and sets it away from any deep public regulation, at least regarding its societal and ethical implications. As Dr. Altmann (U of Dortmund, Germany) puts it: "...Military applications are mostly left out of technology assessment, societal implications analyses, etc. This is particularly worrisome since the military will prepare the very destructive uses [of nanotechnology] that one normally would like to prevent by all means (and there may be destabilization, proliferation, new terrorist threats, and general dangers for humans and society)...The argument that not much is known about military uses is no longer valid." And remarks: "...a variety of views makes this issue contentious. The US National Nanotechnology Initiative has a large military share that mostly stated is the narrow view that US technological superiority is good – neglecting interactions in the international system, potential future threats from terrorist attacks, etc. EU Nanotechnology Programmes have no room for considering peace-endangering aspects up to now.”

In this context, Dr. SudbØ (Norway) has said: "...there is always a need for public regulation of defense and security". Dr. Shimada (Japan) added, "...it is important to have common sense in this problem”.

Dr. Julián González-Estévez from the Applied Physics Department at the University of the Basque Country (Spain) also expressed: "...I am favorable and I consider that particular regulation should be developed according to the new advances.”

A similar position for a “need of certain regulations” was suggested by Dr. Rosa M. de la Cruz from the Physics Department of de University Carlos III (Madrid, Spain); Dr. Wolbring (University of Calgary); Boeing (Germany), Dr. Vanbésien (France); among others.

ETC Group’s Dr. Wetter concurred: “...there is need for regulations on defense and security applications of nanotechnology. Beyond obvious threats to human life and the environment from new chemical, biological or conventional weapons developed using nanotechnologies, there are also threats to privacy (from nano-scale sensor applications) and to democracy and dissent.”

Likewise Dr. Theron (France) acknowledged: “...impacts of nanotechnology can be huge and specific regulations will be necessary. Nanotechnology will enhance defense and security capability but might also be used to control human activity. Therefore political aspects might be the most important.”

Philosopher Shew (Virginia Tech, US) even specified: “...our current laws about spying and intrusion may need to be strengthened or modified, but I think we can deal with security issues in relation to nanotechnology rather ‘easily’. On the contrary, military defense issues are always going to be problematic. Nanotechnology might just make things harder to detect, but the socio-ethical aspects of defense will remain the same. We will still have the same concerns about when use of weapons is justified, whether if is alright to target civilians, etc.”

Dr. Savage (EPA, US) considered that in fact: “...there will be definite ethical issues related to the development of weapons, as there always are. How these concerns can be addressed in a world where military power is aggressively sought after and tenaciously held, is another matter. In addition, the secrecy surrounding many military applications, for any technology not just nano, renders it more than difficult to asses how these developments might pose ethical questions, who is best positioned to deal with them and what potential solutions might be developed.”

Considering that US is at the head of military nano R&D spending worldwide, Dr. Foladori’s impression is that, “...the US is interested in finding a way of going to war ‘without’ casualties. But the more unequal the war technological equipment, the response will be more brutal, full of terror and radical. This is an endless road of surveillance and terrorism.” And he concludes: “...The idea under an endless techno war development is that enemies could be reduced technically. This shows an egocentric superiority ethical position than underscores social problems and continuates the imperialist ideology.”

Dr. Berube (USC, US) expressed a comparable concern but in a more conservative way. He said: “...I have expressed concern that as our soldiers and war fighting becomes less expensive to us in terms of losses, it makes the decision to fight easier to make and that shift in thinking about war fighting troubles me.”

Furthermore, Treder (CRN, US) presages that, "...the most threatening and least understood danger is nanotech-enabled war. The massive increase in weapons potential that molecular manufacturing will offer could rapidly shift and destabilize present balances of power. All-out war between two or more rivals is a real danger, as is the possibility of one nation or group rising to global dominance; *nano-tyranny* could be very ugly indeed."

The warning of Dr. Lin (Nanoethics Group, US) is then worth of double notice: "...if we can learn from history, we seem to be at an important point in science history where we are potentially opening another Pandora's Box (with splitting the atom as the first box), particularly if we're harnessing nanotechnology for destructive, rather than constructive, ends. Military research is a slippery slope and can lead to an arms race, so national exuberance in this area should be kept in check with sound foreign policy that encourages understanding, dialogue and diplomatic resolutions, instead of mistrust and uncompromising stances that lead to an arms build-up." Treder is also in agreement as he indicates that: "...it appears that some kind of responsible, enforceable, transparent international treaty regime may be a necessity." This is also supported by Dr. Thomas Ilfrich (Ivcon, Germany) who proposes on his edited book, *Nano + Mikrotec II*, an International Nanotechnology Agency (INA), "...responsible for friendly cooperation and coordination of nanotechnology research and international control." It is the idea, he says, of Geoffrey Hunt from the European Institute of Health & Medical Sciences, University of Surrey) who spoke about an INA in Tokyo in July 2003.

In this context perhaps one of the most precise and defined proposals is the one offered by Dr. Altmann who has been working the issue for several years now. In his latest book, *Military Nanotechnology: Potential Applications And Preventive Arms Control*, he marked eight special areas and proposed how appropriate preventive limits could be designed and compliance verified. Those areas are:

1. Ban on self-contained sensor systems below 3-5 cm
2. Ban on small arms, light weapons and munitions that contain no metal [because of its undetectability with present equipment].
3. Ban on missiles below 0.2-0.5 m
4. Moratorium on non-medical body implants, body manipulation
5. Ban on re-usable armed, mobile systems without crew; at least no aiming and weapon release without human decision
6. Ban on mobile (partly) artificial systems below 0.2-0.5 m
7. Comprehensive ban on space weapons [related to micro-nanosatellites]
8. Uphold and strengthen Chemical Weapons Convention, Biological Weapons Convention

Many other military applications, clarifies Dr. Altmann, pose no great risks or would be so close to civilian applications that limitation would be unrealistic. Nonetheless, very few applications could act positively (e.g. better sensors for biological weapons).

Finally, he adds that, "...the international dialogue on responsible R&D of nanotechnology would be a natural place for debates about such limits, but at least for the time being this does not seem possible."

In general, Altmann remarks, "...in some countries a problematic narrow view of national security from officials, defense planners/researchers, etc., needs to be questioned, optimally by scientists within the country."

This might be particularly needed in the US where unilateralism has characterized the stance of the current US administration towards the ratification of several international agreements.²³

Nanotechnology, Practical Problems and 'Underdeveloped' Countries

Most 'experts' agree that nanotechnology has the potential to solve a number of practical problems, but not all seem to be sure whether the 'underdeveloped world' -as it is tagged- is going to receive the "fruits of nanotechnology" and, if so, to what degree.

Therefore the question is whether these technical solutions will be available for poorer countries, both in terms of price as well as the knowledge that is required to work, operate and develop them; inquires Türk (Wuppertal Institute, Germany).

Philosopher Shew (Virginia Tech, US) believes in this respect that, "...technologies rarely provide for the simple fix we would like. Instead, careful attention to the locality of situations is necessary for the proper deployment of technology in underdeveloped areas. Socio-technical problems with nanotechnology will have to be solved before the technology can be used in practice. If nanotechnology will have potential for these areas, it might first be in the area of water purification. Other examples of nanotechnology may have more complications in being developed to suit a purpose for an underdeveloped country. Our track record when it comes to the adaptation of technology for places where we are not from is mixed, so I would be cautious in saying that we're going to solve a whole bunch of practical problems in underdeveloped countries with nanotechnology any time soon."

Dr. Berube (USC, US) some what agrees as he thinks that nanotechnology "...behooves us to solve problems rather than to use the developing world as a justification for our own self-serving policies. Simply put, clean water would be desirable but we need to not only research and develop the technology, we must find a way to implement it so it can have an impact in developing countries. Unfortunately, we have not met our obligations when it comes to dispensing the fruits of our research agenda".

Similarly, Prof. Irache (Spain) and Dr. Vanbésien (France) consent by remaining skeptical towards to the real possibility of nano to solve the practical problems of the underdeveloped countries. Dr. Vanbésien believes that in addition, "...there are quite some financial interests that pollute the scenario". The main problem, states Dr.

Altmann (Germany), "...is one of economy, distribution, etc., so special efforts would be needed."

What is more, "...there can never be just a techno solution. Changes in the societal framework are needed for any technology to be useful"; says Dr. Wolbring (University of Calgary, Canada). Dr. Foladori (U of Zacatecas, Mexico) consents. For him, "...nanotechnology will be of little advancement, unless a huge change in the socioeconomic structure comes together. Problems of underdeveloped countries are not of lack of technology but of socio economic relations. A new technological revolution will not help much, and in some cases could even worsen disparities."

Dr. Savage (EPA, US) has a similar conception. She expressed that nanotechnology's potential to solve the practical problems of the underdeveloped countries: "...is not that clear-cut. Certainly nano has a potential for alleviating poverty, increasing potable water supplies, providing inexpensive energy sources, and increasing available food supplies. However, it also has a potential to further increase the economic and technical divide between rich and poor [the so called 'nano-divide']; to result in altered soil conditions that may prove disastrous in particular climates or environments; to increase particulate matter in ambient and indoor environments; to result in more powerful and inexpensive destructive weapons; to reduce democracies and increase aristocracies; to create enhanced human performance/capability for those who can afford it leaving a portion of the population doomed to servitude; etcetera."

Correspondingly Dr. Wetter (ETC Group) stated: "...in a just and judicious context, yes, nanotech could help solve the 'practical problems' of undeveloped countries. There could also be global environmental benefits from replacing some conventional materials with new nanomaterials. But in a world where privatization of science and unprecedented corporate concentration prevail, the likelihood that nanotechnology will help solve the problems of poor countries is low. The grab for patents on nano-scale products and processes could mean monopolies on the basic elements that are the building blocks of the entire natural world, and will make it more likely that developing nations will participate in the 'nanotech revolution' only via royalty payments. If current trends continue, nano-scale technologies will contribute to the concentration of economic power in the hands of multinational corporations instead of solving the problems of poor countries."

As with existing technologies, a key challenge will be addressing the concerns of intellectual property, according to Boeing (Germany). And he adds, "...it seems as if the developed countries are repeating the same strategy as they have done in the past with IT, biotech and fabrication technology: securing them by IP regimes and thus not giving underdeveloped countries –which are undercapitalized, too- a chance to catch up without becoming dependent on tech transfers."

Dr. López-Quintela (Spain) is quite conclusive when he asserts that, "...I do not see that nanotechnologies can solve any problems for the underdeveloped countries. If someone tries to propagate this idea, either is hypocrisy or nonsense. The solution for

underdeveloped world countries can be found without nanotechnology: It is a matter of willingness.” Dr. Pérez de Luque of the ‘Alameda del Obispo’, IFAPA-CICE (Spain) adds: “...I think that the main practical problems of the underdeveloped countries are not going to be solved through nanotech. In fact they have not been solved by any technique developed until now. The main problems of underdeveloped countries are both the well developed countries and the mega-corporations who exploit their resources”. Dr. Rodríguez-Cabello (Spain) explains: “...former experience teaches us that underdeveloped countries always have difficulties in solving their problems. In general the solutions do not come exclusively from technological developments. These can be difficult to incorporate into their social structure. It seems that their problems are of a more basic nature such as lack of infrastructures and formation of the people. Only by solving those first, the role played by new technologies could take part.”

Moreover, Dr. Martins (Brazil) remarks: “...previous technological waves were presented as the solution for underdeveloped countries. However these countries still are underdeveloped and, in some cases, even in worst conditions. Thus, nanotechnology is not a unique solution for the underdeveloped countries, the solutions –before de technical ones- are of a political sort...The constraints and possibilities of a transformation of the current process under which the underdeveloped countries are subjugated are outlined, in the field of technologies and in the course of their appropriation. In the case of nanotechnology, as it is a field that is being appropriated manly by the developed countries and their multinational corporations, the possibilities of its appropriation by underdeveloped countries will be extremely reduced.”

In the meantime, Türk (Wuppertal Institute, Germany) proposes an active promotion of technology transfer and technology leapfrogging. Similarly, Dr. Welland (University of Cambridge, UK) believes that what is needed is, “...a sympathetic and partnership based arrangement and not to force western technology onto under-developed countries”; while for Dr. Lamba (Tormacom Ltd, Canada), since the problem lies more on the cost factor it is apparent that “...the undeveloped countries would need financial assistance for utilizing these processes.” However, says Dr. Battista Renaldo from the University of Montreal (Canada), in doing so, “...there is the risk of being perceived paternalistic, if not imperialistic”.

Communication Proposals Among Actors and Communities for Policymaking

Stimulating the Dialogue

“Stakeholders in nanotechnology are hard to identify if we are not referencing a certain technology”, points out philosopher Shew. Since the array of technologies associated with nanotechnology is so vast, she adds, “...different areas of use need to be evaluated separately. ‘Nanotechnology’ is an umbrella term and must be understood that way if we hope to avoid miscommunication.”

In such a framework, Dr. Savage (EPA, US) assumes that, "...nano's impacts, both positive and negative, are best communicated by those engaging in the research, sponsoring the research, and marketing the products." And specifies: "...this has to be a dialogue, however, not merely communication from one side. The opinion of the general public (in whatever form that may eventually take – either via media, public-interest groups, NGO, etc.) should not only be sought but considered and a dialogue initiated based on expressed responses or concerns. This is not a one-shot deal it must be a continual, ongoing and evolving conversation in order to produce meaningful information that society as a whole can then use to go forward."

Shew seems to be in accord, but only as long as the interdisciplinary groups include social scientists, "...so that the context in which science is taking place is recognized by the group[s]." It is a condition that Dr. Lin shares as he realizes that, "...scientists and technologists are generally very poor in responding to media hype and misinformation."

Besides, Dr. Berube believes that "nano is dominated by hyperbole" and that in fact, "...scientists communicate horribly to the public and to policy makers". Hence Dr. Berube infers that, "...the answer is not to educate the public to speak like scientists (that deficit model has never worked), the answer is not to bring some folks together to talk about nanoscience in juries and consensus conferences. The solution rests on solving the media issue since the media is responsible for amplifying and attenuating information for the public. If they do their job well (sic), we will discover the public is well served and can participate as stakeholders." Hence, most of the communication difficulties could be worked out, from what can be derived from the perspective of Dr. Berube, with media training enabled by 'experts'.

In a similar direction, Dr. Pérez de Luque (Spain) considers that, "...independent multidisciplinary committees of experts in nanotech and nanoscience should be created in order to popularize these fields, informing about prospects, the benefits and the risks." Additionally, Ivcon CEO (Germany), Thomas Ilfrich, proposes that independent projects and government sponsored projects should be the mechanisms that stimulate dialogue, however, he critiques the current governmental 'blindness' as it "...does not take independent projects really serious if those are not part of 'their' originally network."

Differing from an 'expert'-vision as a unique option, Wetter believes that, "...any efforts by governments or industry to confine discussions of nanotech policy to meetings of experts or to focus debate solely on the health and safety aspects will be a mistake. It is not for scientists to 'educate' the public and for industry to smooth public acceptance but for society to determine the goals and processes for the technologies they finance. At a time when nano-scale technologies and their convergence are developing faster than public policies can evolve to address them, it is critical to broaden the community of participants who play a role in determining how nano-scale technologies will affect our future. Society must gain a fuller understanding of the direction and impacts of science and technology innovation in a broader socio-political context. To keep pace with technological change, society needs innovative approaches to monitor and assess the introduction of new technologies."

On the topic of what is meant by an 'expert', Dr. Wolbring (University of Calgary, Canada) correctly points out that what we see as an 'expert' is a *cultural construction* with its accompanying pitfalls. Then it seems obvious to ask questions such as: What are the characteristics of an expert? How is such expertise measured? Who defines who is a legitimate 'expert' and who is not?

In any case, Dr. Wolbring suggests that we should be 'practical' in the sense that we need to "...cut the *hype* and lay out all the issues. Work trans-disciplinary and trans-stakeholder [...and even so] on transtechnology analyses."

Proposals for Policymaking Advisory

This is a complex problem, sustains Dr. Lin, because, "...on the one hand, division of labour seems to work: let the experts focus on what they do best. So as it applies to nanotechnology, many scientists and business executives, for example, don't seem too interested in the social or ethical questions, which is fine –that is not their area of expertise. But, still, they play a role in the larger picture of our future, so an enlightened scientist or business person (and these do exist) recognizes his or her personal responsibility." Furthermore, the problem is so difficult also because there are a, "...few people, especially scientists and business people, [that] do not like being told what to do. And they like even less policymakers (who may or may not understand nanotechnology well enough in the first place) who tell them what to do or what their responsibilities are. So it will take time for attitudes to change and open, productive dialogue to occur (as with any impassioned issue). One key seems to be the public, since it is the public who policymakers and businesses ultimately serve. But the public's understanding of nanotechnology is low at best. So educating the everyday person on nanotechnology and nanoethics is important for oversight and to drive industry responsibility."

As follows, for Dr. Vanbésien (France), "...the interdisciplinarity will be an obligated step towards the coherent development of nanosciences. The discussion should be at different levels and I expect it will not be imposed by a too reduced group of experts. In fact, the way in which these committees of experts are generally nominated forbid the total objectivity and consequently establishes political pressures of all types...besides the perennially of a specific group can be problematic. Thus, in order to seriously monitor the evolution of these technologies we must ensure the expertise stability so that eventually we could find a modest solution. This does not mean that we should limit such expertise just to the scientific world, which is not excluded of diverse pressures. Besides, the solution should not limit the creativity of researchers. Instead it should 'control' the area of applicability of the new nanoobjects. Foresights are difficult and often the real original solutions sometimes come from where we do not expect them to."

The relevance of such a discussion and dialogue is so important for Treder (CRN, US) that he warns: "...if politicians, the public, and pundits do not get a grip on the dangers we are facing, it could be too late to respond effectively and advert them. On the other

hand, if nanotech's wondrous potential benefits are not fully appreciated, then irrational fear could delay or prevent them altogether, denying better health, prosperity, and fuller lives to billions of peoples."

Therefore, he additionally states: "...the challenge of achieving the goals and managing the risks of nanotechnology requires more than just brilliant molecular engineering. In addition to scientific and technical ingenuity other disciplines and talents will be vitally important. No single approach will solve all problems or address all needs. The only answer is a collective answer, and that will demand an unprecedented collaboration –a network of leaders in business, government, academia, and NGOs. It will require participation from people of many nations, cultures, languages and belief systems. Never have we faced such a tremendous opportunity before –and never before have the risks been so great. We must begin building bridges."

Those bridges, as conceived by Dr. Berube, seem to have their foundations in the so-called SEIN groups or Societal and Ethical Implications of Nanotechnology groups; a sub-class of multidisciplinary groups of "enablers" whose particularities change depending on how they are visualized by each cluster and/or community. Their role for policymaking advisory it is being quite extensively accepted although the particularities, not only of such groups but also of the process of evaluation and advisory itself, may diverge widely.

Ilfrich for example considers that interdisciplinary 'experts' groups "are absolutely necessary". The mix of the findings of such groups with independent wide-open surveys is a parallel acceptable alternative, however, this is not true in the case of public consultancy or even in public referendums since, for Ilfrich, "...those bring only endless/aimless discussions."

It is a conception shared by Dr. Vanbésien who believes that "...a referendum is not an adequate solution. Such a parliamentarian debate would be sufficiently difficult to carry out in a calm way, and so would the pedagogic effort of scientists which would be important in order to respond to alarmist positions of all nature."

Dr. Lin concurs with Ilfrich and Vanbésien but alerts that, "...individuals able to do such multidisciplinary studies are very few in number." In addition, even though he sees public surveys as a "good thing", nevertheless he suggests being careful since "...a major issue is how one interprets and acts upon such surveys."

In contrast, Dr. Lamba (Tormacon Ltd, UK) is categorical when he states that, "...there is no need of open surveys. Only the specific focus groups are required [since] It is a very specific sector, and a highly perceptive inter-disciplinary group can be quite effective."

Dr. Pérez de Luque (Spain) differs completely as he agrees with the viability of the instruments mentioned before and even with the public referendum mechanisms, "...but only if the population is really well informed about the topics." Following the actions of

educating the public, entering in a discussion and then beginning a dialogue, adds Dr. Savage, "...such a referendum would provide useful input and result in a well-considered decision, but not before." Boeing instead recommends: "...to consider the implementation of referendum mechanisms once a kind of disruptive nanotechnology has been demonstrated." Furthermore, he conveys, "...the nanotechnology community should make clear where they put proactive limits into place not waiting for regulation by government bodies. We definitely need a self-restriction of the nanotechnology community."

Apparently in accord with Dr. Altmann's concern on the veracity that "on policy advice, there is always the risk of technocratic approaches", Dr. Foladori sustains that "...interdisciplinary groups [can] help scientists to widen their opinion and focus, but hardly helps to adjust technology policies to the interest of peoples at large." Then, Dr. Foladori believes that, "...only organized societal groups have the power to make their interests become incorporated in public agenda. The following discussion has to reach trade unions, cooperatives, and people's mass organizations that would have not only an opinion and participation 'light road', but also the possibility of reacting with social force." Dr. Martins (Brazil) agrees by calling to avoid the tendency of restricting the debate to the ones that "understand the issue" and instead opening it to the citizens and what he calls the "social insurance"; meaning citizens as active agents in the process of decision-taking.

For the moment, Boeing remarks on the necessity of a classification of nanotechnologies (mentioned before) as this might be helpful in carrying the dialogue forward.

Resembling the proposal of Hunt and Ilfrich of an International Nanotechnology Agency, Dr. Wetter offers the recommendation to, "...create a new United Nations body with the mandate to track, evaluate and accept or reject new technologies and their products. To this end, ETC Group has put forward a proposal for an International Convention on the Evaluation of New Technologies –which would be an intergovernmental and transparent facility capable of earning the confidence of governments and society as well as of the scientific community."

Towards a Dialogue Methodology for Policy of Nanotechnology Implications

Even though there are the sometimes wide-open divergences, it is obvious that there is a general accord on the necessity of taking forward the dialogue on nanotechnology aspects and implications.

With that purpose in mind and not with the purpose of legitimating *in advance* any nanotechnology application, it is proposed the following dialogue methodology for policy.

As it will be seen, it corresponds with several proposals recommended by the ‘experts’ who participated as part of the Nano-Conceptions survey.

Following the proposal of Dr. Strand (November, 2001) on his memo to the *COST Nanoscience and Technology Advisory Group* of the European Commission the key aspect of the methodology in question is the consolidation of a community of “enablers” (here we are using Dr. Berube’s categorization). Nonetheless, this community, as proposed here, has quite particular aspects since it does not intent to be *under any circumstance*, either functional to established interests or become “...a public relations division for commercial [or military] nanotechnology”.²⁴

First, because of the expressions and words used are important in an attempt at dialogue in a complex environment of conditions, such a community has been denominated here as a community of *specialists* in Environmental, Ethical, Legal and Social Aspects of nanotechnology, which is integrated by different clusters and sub-clusters of (E)ELSA groups. Examples are the previously mentioned SEIN groups, the well-known ELSI groups²⁵, the Science, Technology and Society studies, the Real Time Technology Assessments, or others involved with innovation research, foresight exercises, risk assessments, etc.

Thus, the (E)ELSA community²⁶ is an umbrella of clusters and sub-clusters of specialists working on the complexity and uncertainty of science in a broad sense and concerning the practical problems (on societal, ethical, environmental and legal aspects, among others). In this sense the (E)ELSA community is just a straightforward way of referring to such diverse community of specialists as one entity, even though there are of course major perspective and methodological differences among the concrete groups and actors.

Nonetheless, even with the presence of such a diversity of groups, it seems that the “ideal” ELSA working groups -with such diversity within its own structure- are yet to be developed since most of the current groups are still embedded within their own particular vision and are limited to their closest colleagues.

Dr. Strand has noted that there are in fact several arguments that might lead us to encourage the demand of this type of studies of nanoscience and nanotechnology. Accordingly with Strand, those are:

- (i) The need to understand public perceptions and attitudes before the launch of new technology,
- (ii) The recent advancements in the academic fields concerned with such studies,
- (iii) The weak but distinct trend of a growing social and ethical concern inside the sciences,
- (iv) And above all, the presence of good reasons for being ambivalent and ethically and socially concerned about new and possibly powerful sciences and technologies.

Of course, he adds, "...it remains to specify somewhat more concretely what exact issues to follow and which methodologies apply. This is in part a matter of the research process itself and thus it cannot be answered fully yet".²⁷

In the meantime, a general sketch on the mentioned dialogue methodology and the role of the (E)ELSA community can be worth looking into in order to take the dialogue and debate forward. Evidently it is a limited proposal as, for example, it does not necessarily overcome, paraphrasing Thomas Kuhn²⁸, the relation of modern science and technology (e.g. nanoscience and nanotechnology) with society and the culture in which it is produced (the capitalism production system).

It is known that there are well-established channels of communication among some clusters of the diverse communities (natural and social sciences, government, private sector and society communities) not only at a level of intra-community but trans-community as well. Nevertheless, there are also serious communication gaps among other clusters and even entire 'chunks' of communities (this includes the case of the (E)ELSA community as well). In part because of the different language and interests.

These communication holes cannot be easily filled, as there are several constraint factors. For example there is an important degree of distrust among actors (as happened with several replies to the survey participation call).

Besides, several actors do not have time to express their opinions, an aspect that constantly obstructs the stream of communication. This is very common among scientists, and the private sector and government communities. A solution could be explored based on the principle of 'social responsibility'. Under that principle, for example, scientists' evaluations should include their activities in communicating and 'vulgarizing' their research. One must realize that as science and technology are achieving levels of increased complexity and uncertainty, it is no longer valid to blame the 'lack of time' as a factor for a deficient communication.

Of course it is obvious that researchers have to keep doing what they do best: research. The same is valid for politicians, social scientists, NGOs, unions, cooperatives, businessmen, and so on. Nevertheless, it seems to be our *social responsibility* to devote our time and willingness. The new generations' rights might be at risk.

In this context the role of (E)ELSA specialists figures as a strategic one not only because of their peculiar multidisciplinary background but also because they can give a 'full-time' effort to built communications "bridges" among all actors.

However, "ideal" ELSA specialists groups must fill some general but rigorous characteristics in order to avoid, as much as possible, any "technocratic" affinity and approaches.

In this sense, an (E)ELSA group must include the same number of specialists coming from each community. It must incorporate (a) specialist(s) from each relevant cluster related to the application to discuss. The designation of 'relevant' clusters in any case can exclude the participation of members of any community as a whole.

The specialists should be publicly approved and designated by their own cluster and should not work in the same group for more than one project. New generations of ELSA specialists must have the will to enrich and expand the ELSA community clusters and reconstitute the old generations in a reasonable period of time.

As indicated in Image 2, the group should enable the communication of all communities and its clusters by dialoguing directly with them in an open, active and productive dialogue scheme. The involvement of such communities with the (E)ELSA groups should be enforced in a reasonable way.

The specialists must work together in a multidisciplinary and transdisciplinary way. This means that a specialist, for example from the society community, will have to learn to communicate with colleagues of other clusters and communities not only inside the ELSA working group but also outside of it.

Because of that, no division of labor is valid inside the ELSA group in the sense that, for example, a specialist with a background in social sciences should not assume and carry out the dialogue process within 'her/his' own cluster and community alone or with colleagues of the same community.

The technological application area to be reviewed should be the subject of study of more than one (E)ELSA group. A limited number of (E)ELSA groups with a guaranteed diversity of school of thoughts should conform the public programs on this kind of evaluations as a conventional way of operation...at least in strategic scientific and technological fronts.

The funding sources should be public²⁹ and must be managed by public universities that would function as operative head quarters of the different ELSA groups (this last function can be shared with private universities).

The findings of the evaluations of the diverse (E)ELSA groups should be published separately and discussed later among themselves. A final and unique text should be produced by such (E)ELSA groups for the advisement of policymakers in each country and integrated regions (it should also be published before any resolution is taken).

The final evaluation should have a bearing on the process of regulation in the sense that it might impede a regulation that contradicts the evaluation itself by establishing a moratorium until the issue is taken either into a new evaluation process or to public consultancy/referendum.

In the case of international agreements, (E)ELSA specialists should be included in the negotiation processes as key advisors. Once the (E)ELSA groups' evaluation has been done, new groups should be established for a revision of the process after a defined period of time.

Finally, ELSA groups must have to be subjected of evaluation by other specialized ELSA groups who monitor and evaluate the work of the first ones under the same mechanisms explained above.

****This proposal in any case calls for a delegitimization of the already operative 'non-ideal' (E)ELSA groups or other dialogue mechanisms and debates. It is only suggested as a parallel mechanism that, because of its characteristics, might take the dialogue forward while enriching it.****

Preliminary Recommendations:

Governments of the US, EU and Japan –as the leaders of S&T development- should implement a pilot project of at least three independent ELSA groups for reviewing, for example, the case of converging technologies. These must include 'local' and foreign ELSA specialists in order to avoid ethnocentric perspectives. Their results should be published and widely discussed for a possible broader implementation.

A parallel exercise must be done in the cases concerning defense, military and security nanotechnologies applications with the purpose of defining and creating a general international proactive agreement on regulation/prohibition of such applications in a period no longer than five years.

Other countries should implement as well this type of mechanisms, but in relation to their own reality and particularly in the S&T areas in which there is a higher public concern.

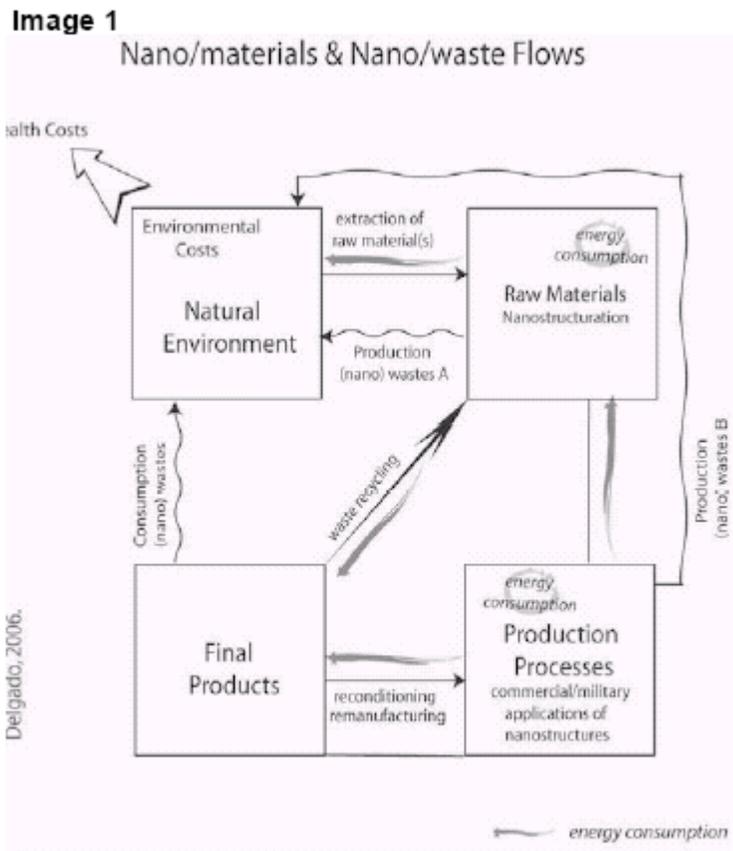
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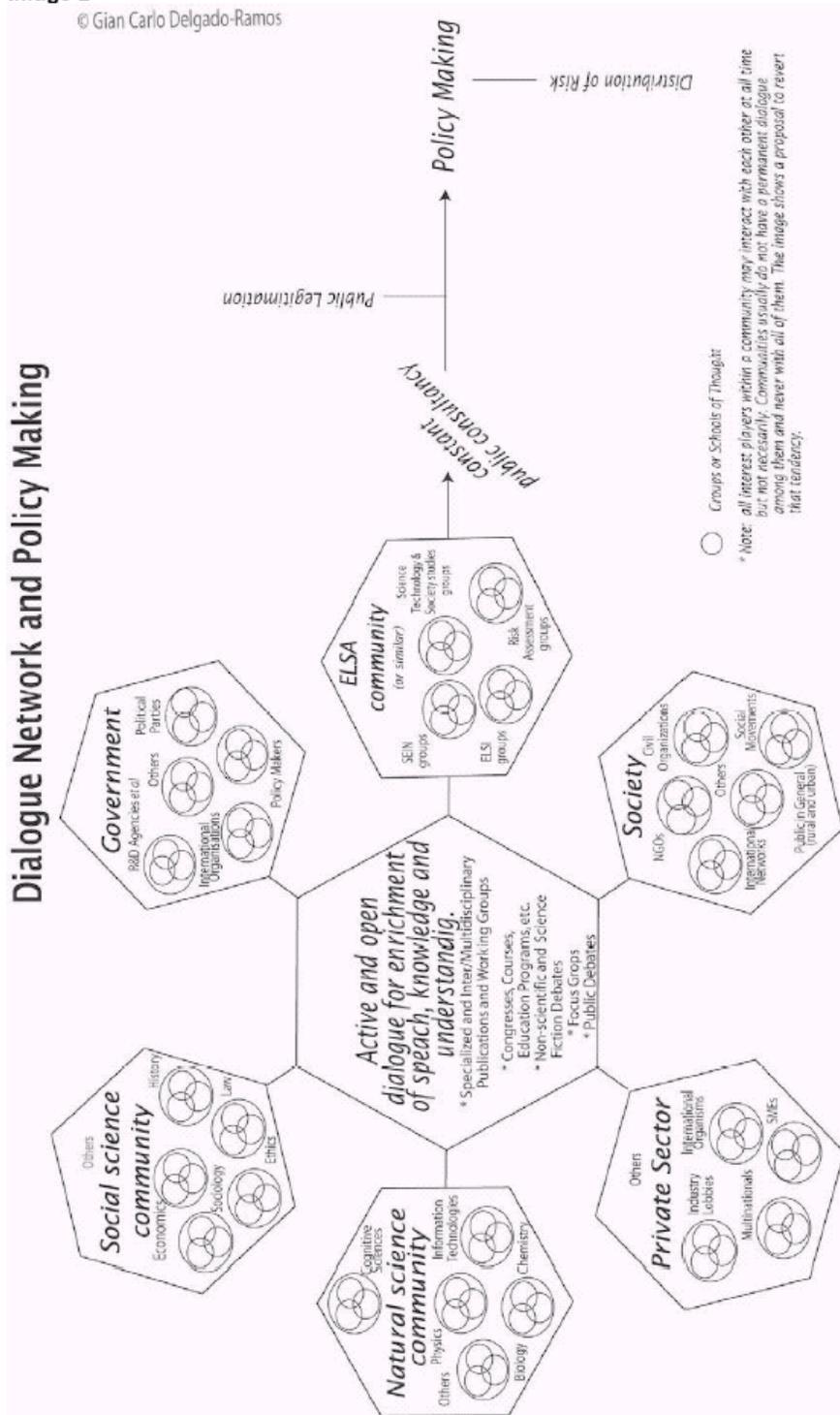
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Source: Own elaboration. Based on Ayres' materials-flows scheme. See: Ayres, Robert (1994), "The Industrial Metabolism: Theory and Policy", in *The Greening of Industrial Ecosystems*. National Academy Press, Washington, US.

Image 2
 © Gian Carlo Delgado-Ramos



¹ This Report has been published in two formats. The “HTML” version of the Report has been modified in order to make it “web-friendly” and consistent with the publication format of the *Journal of Philosophy, Science & Law*. Please refer to the “PDF” version of the Report if the original format is preferred.

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³ One of the main references of this debate is one held between Eric Drexler and Richard Smalley (who passed away at the end of 2005). See: “Drexler and Smalley make the case for and against ‘molecular assemblers’” *Chemical & Engineering News*. Vol. 81. No. 48: 37-42. December 1, 2003.

⁴ Quotations have been directly taken from written answers to the survey, except when specified; all contributions are person-specific and do not necessarily represent the position of centers, agencies, etc, where the contributors work.

⁵ See: Nowonthy, M., *et al* (1994). *The New Production of Knowledge*. Sage Publications. London; and, Funtowicz, S (1990). *Uncertainty and Quality in Science for Policy*. Kluwer Academic. London.

⁶ Strand, Roger (2001). “ELSA Studies of Nanoscience and Nanotechnology”, MEMO to the COST Nanoscience and Technology Advisory Group (NanoSTAG). November 16.

⁷ *Ibid.*

⁸ Mehta, Michael (2003). “Nano-hype”, *AgBiotech Bulletin*, 11(6), 5-6.

⁹ Delgado, Gian Carlo quoted in: “Down to the nearest billionth”, *RTD Info Magazine*. European Commission. No. 47. January 2006.

¹⁰ I presented, as a poster, a preliminary proposal of such a methodology at the *Euro Nano Forum 2005* (5th-9th September. Edinburgh, Scotland).

¹¹ The author reserves the option to present his well-positioned writings, from a social community perspective, at a later date and in a different forum.

¹² For an appreciation on the converging technologies as conceived by the United States (Nano-Bio-Info-Cogno), see: Roco, Mihail and Bainbridge, William (2002). *Converging Technologies for Improving Human Performance*. National Science Foundation. US. For the case of the Converging Technologies for the European Knowledge Society (Nano-Bio-Info-Social Sciences): Alfred, Nordmann (Rapporteur) (2004). *Converging Technologies – Shaping the Future of European Societies*. European Commission. Brussels, Belgium.

¹³ “Electro-vision”, *New Scientist*. 21 January 2006: 33-35.

¹⁴ Baum, R (1986). “Scanning tunneling microscope achieves atomic resolution”, *Chemical and Engineering News*, 64, 22-25. Quoted in Baird, Davis and Shew, Ashley (June 2004). “Probing the History of Scanning Tunneling Microscopy”. University of South Carolina. US. Downloadable at: <http://cms.ifs.tu-darmstadt.de/fileadmin/phil/nano/baird-shew.pdf>

¹⁵ Ravetz, 1971. *Op cit*: 78, 89.

¹⁶ See: Weiss, Rick (2006). “Nanotech Product Recalled in Germany”, *The Washington Post*. April 6. Also: “Kleinmann pulls nano product”. Kleinmann web page: kleinmann.net/html/index.php?name=News&file=article&sid=117 For a preliminary statement from the industry see: Von Bubnoff, Andreas (undated). “Study shows no nano in Magic Nano, the German product recalled for causing breathing problems”, *SmallTimes*. US.

¹⁷ 1) Roco, Mihail C., and Bainbridge, William S (March, 2001). *Societal Implications of Nanoscience and Nanotechnology*. National Science Foundation. United States. 2) Renzo, Tomellini and Roco, Mihail C (February, 2002). *Nanotechnology Revolutionary Opportunities and Societal Implications*. European Commission. Belgium. 3) Environmental Protection Agency (August, 2002). *EPA Nanotechnology and the environment: Applications and Implications*. Washington, US. 4) Roco, Mihail. C, and Bainbridge, William S (December 3-5, 2003). *Nanotechnology: Societal Implications – Maximizing Benefits For Humanity*. National Nanotechnology Initiative. United States. 5) Royal Society (July, 2004). *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*. London, UK. 6) Department for Environment, Food and Rural Affairs (2005). *Characterizing the Potential Risks Posed by Engineered Nanoparticles*. UK Government. London.

¹⁸ 1) Hett, Ammabelle (2004). *Nanotechnology: Small Matter, Many Unknowns*. Swiss Reinsurance Company. Switzerland 2) Lauterwasser, Christoph (June, 2005). Opportunities and Risks of Nanotechnologies. Allianz AG Center for Technology / OECD. London.

¹⁹ 1) ETC Group (January, 2003). *The Big Down: From Genomes to Atoms*. Canada; 2) Arnall, Alexander H (July, 2003). *Future Technologies, Today's Choices*. Greenpeace Environmental Trust. London, UK. 3) Miller, Georgia (May, 2006). *Nanomaterials, Sunscreens And Cosmetics: Small Ingredients, Big Risks*. Friends of the Earth. Australia/US. Etcetera.

²⁰ Namely the work of Nanologue, an European FP6th sponsored project (www.nanologue.net); the research carried out by the International Council on Nanotechnology at Rice University (<http://icon.rice.edu/index.cfm>); the evaluations of the International Risk Governance Council (www.irgc.org/irgc/projects/nanotechnology/); the publications of the Center for Responsible Nanotechnology (www.crnano.org/); the work of the Woodrow Wilson International Center for Scholars through its project on Emerging Nanotechnologies (www.nanotechproject.org); the work done by the NanoEthics Group (www.nanoethics.org); or the quite numerous publications and institutional projects of the International Nanotechnology and Society Network (www.nanoandsociety.com/), among others.

²¹ See, for example: a) Georgescu-Roegen, Nicholas (1971). *The entropy law and the economic process*. Harvard University Press. Cambridge; b) Martínez-Alier, Joan (1987), *Ecological Economics, Energy, Environment and Society*. Basil Blackwell. Oxford; c) Eurostat (March 6, 2001). *Economy-wide material flow accounts and derived indicators*. Statistical Office of the European Communities. Brussels; d) Adriaanse et al (1997) *Resource flows*. World Resource Institute. Washington, US; or e) Ayres, Robert U., y Simonis, Udo E (1994). *Industrial Metabolism: Restructuring for Sustainable Development*. The United Nations University. Tokyo/New York.

²² These aspects are also recognized in: Roco/Bainbridge, 2001: 13-16; Altmann, Jürgen (2006). *Military Nanotechnology: Potential Applications And Preventive Arms Control*. Routledge: section 1.4; and, Anton et al (2001). *The Global Technology Revolution: Bio/Nano/Materials Trends and their Synergies with Information Technology by 2015*. RAND: Santa Monica, CA.

²³ Exemplifying: the US has not ratified the Comprehensive Test Ban Treaty. It has been accused of some how violating the Nuclear Non-Proliferation Treaty by celebrating a civil nuclear agreement with India. It has not signed the Kyoto Protocol, neither the Convention on Biological Diversity.

²⁴ Berube, 2005. Op cit: 313. Berube refers to such functionality as a "masking function of SEIN research" (Ibid: 312)

²⁵ Ethical, Legal and Societal Implications (ELSI) groups were quite common for evaluating the ethical implications of biotechnology or bioethics. Some sounded cases are the studies concerning the Human Genome Project.

²⁶ (E)ELSA community must not be confused with the Ethical, Legal and Social Aspects groups or ELSA groups which with particular methodological differences, are quite similar to ELSI groups.

²⁷ Strand, November 2001. Op cit.

²⁸ Kuhn, Thomas S (1970). *The Structure of Scientific Revolutions*. The University of Chicago Press. US.

²⁹ Private sources can be funneled through tax imposition mechanisms.