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# Appendix

to the

# Nanologue Mapping Study

Summary of key findings from a literature study on  
ethical, legal and social aspects of nanotechnologies

Released September 2005

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This paper is a joint publication of the Wuppertal Institute (WI), EMPA, Forum for the Future (FFF) and triple innova (TI). It was written by Volker Türk, Sören Stöber, Dr. Christa Liedtke (WI), Dr. Hans Kastenholz, Andreas Köhler (EMPA), Hugh Knowles, Tim Aldrich (FFF), Michael Kuhndt, Stephan Schaller (TI).

## 1. Introduction

This document is an appendix to the “Nanologue Mapping Study<sup>1</sup>”. It presents the key findings of 15 studies or reports that were chosen among more than 100 nanotechnology related publication for more detailed analysis. Studies are listed in alphabetical order of the organisations name on which behalf they have been written or published:

1. ESRC (2003): The Social and Economic Challenges of Nanotechnology.
2. ETC Group (2004): DOWN ON THE FARM.
3. European Commission (2004): ‘Nanotechnology – Innovation for tomorrow’s world’.
4. Greenpeace Environmental Trust (2003): Future technologies, Today’s Choices. Nanotechnology.
5. IOEW (2004): Effects of the production and use of nanotechnologies on sustainability.
6. IOEW (2004): Nanotechnology and Regulation within the framework of the Precautionary Principle.
7. komm.passion (2004): Wissen und Einstellung zur Nanotechnologie [Knowledge about and Attitudes towards Nanotechnology].
8. Meridian Institute (2005): Nanotechnology and the Poor.
9. Munich Re: Nanotechnology – What is in store for us?
10. Nanoforum.org (2004): Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology.
11. Paschen et al. (2004): Nanotechnologie. Forschung, Entwicklung, Anwendung [Nanotechnology. Research, Development and Application].
12. RAND (2001): The Global Technology Revolution.
13. Royal Society (2004): Nanoscience and nanotechnologies: opportunities and uncertainties.
14. Swiss Re (2004): Nanotechnology - Small matter, many unknowns.

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<sup>1</sup> Nanologue Mapping study. Summary of key findings from a literature study on ethical, legal, and social aspects of nanotechnologies. A joint publication of the Wuppertal Institute, EMPA, Forum for the Future and triple innova. Available at [www.nanologue.net](http://www.nanologue.net).

15. VDI Technologiezentrum (2004): Nanotechnologie als wirtschaftlicher Wachstumsmarkt [Nanotechnology as an economic growth market].

Within each chapter, a brief summary describes the context of the screened study followed by different sections presenting key results. Information found on nanotechnology applications with specific relevance to ELSA as well as the ethical, legal, social and environmental (if relevant) aspects that were mentioned are presented. Additionally, goals, suggestions and recommendation by the authors are listed.

**DISCLAIMER:** The information provided is a compilation of information, references, quotes and sources that primarily serves to inform the following work packages of the Nanologue project. The authors do not claim to provide a comprehensive overview of existing publications about nanotechnology and related ELSA statements nor to have conducted an in-depth analysis. The document is a compilation of different aspects and perspectives found in the literature. However, the authors would like to share the current state of investigation with a wider audience in case they might find it useful.

## 2. Key findings of the screened reports

### 2.1 ESRC (2003): The Social and Economic Challenges of Nanotechnology.<sup>2</sup>

#### **Summary**

The Economic and Social Research Council (ESRC) concerns about social, political and economic effects of nanotechnology (NT) are the reason why this report was written. It sets out the technological potential of NT and illustrates the issues that NT raises for society as a whole.

#### **Key findings**

The aim of the first section is to present the scientific and technological context of NT. For the most part of this chapter the authors go into detail e.g. by describing aspects of nanoscale science and technology such as scanning probe microscopies or single molecule techniques. Moreover, three areas of applications, namely material science, electronics/optoelectronics, and medical science are illustrated.

Section two deals with commercial applications of NT. In addition to commercial applications of the three areas mentioned in section one, the authors identify applications in the fields of cosmetics and foods; military, space and security; environment and energy and molecular manufacturing.

The whole next section of the report refers to “The Nanotechnology Debate”. Without taking a certain position, the authors describe conceptions and the social and economic effects of NT discussed within the literature. The ESRC report argues that conceptions of NT can be divided into “radical discontinuity” (nanobots, drexlerians etc.), “cautious evolutionism” (more sceptical), “nanotechnology champions” (NT promoters) and finally “nanotechnology commentators” (focus on particular aspects e.g. implications). Social and economic effects of NT are divided into “utopian and dystopian

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<sup>2</sup> Wood, S., Jones, R. and A. Geldart (2003): The Social and Economic Challenges of Nanotechnology. Edited by Economic and Social Research Council (ESRC) (2003). Swindon, 2003.

visions” (positive/negative visions of the future), “barriers to development” (e.g. public acceptance) and “regulatory response”.

NT and its social dimension is the topic raised in the last chapter. A set of key issues and sub-questions for social sciences are mentioned, namely: issues related to ensuring that NT develops its potential (e.g. R&D investment); issues relating to social awareness of NT and public involvement in science (e.g. ethical issues); social and economic issues that will be concurrent with NT (e.g. intellectual property); issues associated with any new technology (e.g. managing the unforeseeable); issues unique to NT (e.g. human-machine interface).

“The Social and Economic Challenges of Nanotechnology” gives a detailed overview on scientific context, commercial applications as well as on the current debate on NT. It does not link specific NT applications to certain ethical, legal and social aspects (ELSA).

This report is edited by UK-based ESRC, which “aims to provide high quality research on issues of importance to business, the public sector and government.”<sup>3</sup> “The Social and Economic Challenges of Nanotechnology” has been produced by a team of practitioners drawn from the social and physical sciences (Wood/Jones/Geldart).

### ***NT applications covered and related ELSA***

ESRC report is covering a series of commercial NT applications but lacks to link these applications to the related ELSA. None the less, other parts of the report deal with ELSA, but more in illustrating the different and divergent positions towards NT. Thus, details on different NT areas of application and if mentioned, related ELSA are listed below.

As regards convergence of NT with other technologies, it is said that many of the applications arising from NT are in itself the result of the convergence of several technologies. “It is probable that advances in biotechnology and information technology will have an equally important, and in many cases complementary, role in the advent of new products and processes.”<sup>4</sup>

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<sup>3</sup> Economic and Social Research Council. Online available: <http://www.esrc.ac.uk>

<sup>4</sup> Wood et al. (2003), p. 23.

**Materials**

- NT is seen as a technology offering a lot of improvements in the field of materials. Yet many products in the field of new materials are already commercialised such as smart textiles, composite materials or coatings. Nanocomposite plastics, carbon nanotubes and nanoparticles are mentioned and described as possibilities for a multitude of applications.
- Specific risks in the field of materials applications are not mentioned.

**Electronics and information technology**

- The main implication of NT for electronics and information technologies is seen to be in the field of an enhancement in product capability. Among others, smaller, faster, cheaper and more effective computers, microscale circuits, and display devices are mentioned.
- Specific risks in the field of electronics and information technology are not mentioned.

**Medicine and health**

- This area of NT applications is seen as one of the most potentially valuable, with many expected benefits to humanity. Fields mentioned are implants and prosthetics, diagnostics and drug delivery.
- Specific risks in the field of medicine and health applications are not mentioned.

**Cosmetics and foods**

- Applications in the cosmetics and food sector deal with novel food which can deliver specific nutrients or drugs to the consumer as well as with shampoos and skin creams which contain nanoparticles with the ability to deliver the desired ingredients to where it is needed.
- Specific risks in the field of cosmetics and foods applications are not mentioned.

**Military, space and security**

- The military sector is aiming to improve the survival of the soldier of the future, to create a 21<sup>st</sup> century battle suit and to develop lighter and stronger weapons and equipment.
- In addition, research concentrates on improving the human machine interface. Moreover, the report addresses civilian security equipment using improved DNA techniques or electronic detectors.
- “Improved materials, lighter but with tough, heat resistant properties, are being used in the design and construction of spacecraft and satellites, and this process will gain from nanotechnology.”<sup>5</sup>
- The authors state that the field of military use of NT is one of the most funding intensive in the world.
- Specific risks in the field of military, space and security applications are not mentioned.

### **Environment and energy**

- NT research in the field of environment and energy is linked to the quest to prevent and reserve environmental damage. According to the authors, NT will provide efficient and effective filters for water and air to reduce pollution. Improved catalysts to reduce waste are already in use (e.g. petrol or chemical processing). A potential impact to society is seen in the area of fuel cells and photovoltaics: “Taken together, improvements in sources of renewable energy, with the development of storage gaseous hydrogen and the improvement of fuel cells, could lead to a viable ‘hydrogen economy’ in which the energy needs of society were no longer reliant on fossil fuels.”<sup>6</sup>
- Specific risks in the field of environment and energy applications are not mentioned.

### **Molecular manufacturing**

- The last area of NT application dealt with is “molecular manufacturing”. “The hope is, that in the future, each home will

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<sup>5</sup> Ibid, p. 22.

<sup>6</sup> Ibid, p. 22.

have its own self-assembly unit that can construct anything the user requires, using blueprints purchased by the designer.”<sup>7</sup> Furthermore, using molecular manufacturing could reduce poverty in developing countries via creating material abundance.

- Specific risks in the field of molecular manufacturing are not mentioned.

### **General**

- A general problem addressed is the uncertainty surrounding NT. Due to this, an assessment of NT’s societal implications is said to be a difficult challenge.
- The authors claim that research on social implications of NT should be of high priority.

### ***Additional information, comments***

- As regards public dialogue it is stated that the needs of society must be considered as a part of the development process. “This implies that any assessment of possible social and economic effects be incorporated into this process as early as possible, and hence that social science, as a major provider of such understanding, can help shape the future of nanotechnology.”<sup>8</sup>
- To develop a realistic perspective on NT is seen as one of the most important challenges to meet.

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<sup>7</sup> Ibid, p. 22.

<sup>8</sup> Ibid, p. 39.

## 2.2 ETC Group (2004): DOWN ON THE FARM.<sup>9</sup>

### *Summary*

The ETC Group, an international civil society organisation, provides a comprehensive look at what impact nano-scale technologies will cause on farmers, agriculture and food production. The report illustrates recent and future applications of Nanotechnologies in agriculture and food production and highlights undesirable implications.

### *Key findings*

- Nanotechnologie application in agriculture can cause similar threats to farmers as gentech, especially a loss of the farmers self determination and autonomy (e.g. seed replication). Dependencies of the public from non-democratic business mechanisms.
- There is a lack of regulations (on national and international level) those addresses the nano-scale properties of Chemicals and the societal and environmental impacts. Nano-products came to market in the absence of regulation and societal debate.
- Nanotechnologie patents can have profound impacts on the entire food system and all sectors of the economy. NT patents promote technological gap between north/south, large farmers/small farmers. Proprietary NT forces corporate concentration all along the food chain. That will strengthen the grasp of agribusiness over farming and global food production.
- Society – including farmers, civil society organisations and social movements – must engage in a wide debate about nanotechnology and its multiple economic, health and environmental implications. Society needs to become fully engaged in a wide discussion of the role of converging (nanoscale) technologies in food and agriculture.
- ETC Group calls therefore for an immediate moratorium on laboratory experimentation and the environmental release of NP and synthetic biology.

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<sup>9</sup> ETC-Group (2004): DOWN ON THE FARM. The Impact of Nano-Scale Technologies on Food and Agriculture. Ottawa, Canada.

***NT applications covered and related ELSA***

- **Nano conditioning of seeds:** An application of nano-scale methods to enhance productivity in agriculture forces corporate concentration. Intellectual property and patents will increase the dependencies of farmers on large companies.
- Precision **agriculture:** NT based miniaturization of computing promote automated, centrally-controlled, industrial-like agriculture. Concerns about a loss of privacy and self-determination of farmers and consumers are raised.
- Social and ethical implications and potential risks associated with synthetic **biology and nanobiotechnology:** modified plants to produce designer substances for nutrition (food) and pharmacy (enhancing the human body).
- **Nano-encapsulation of pesticides:** risk of environmental pollution and poisoning in food chain.

***Additional information, comments***

Study talks about the convergence of NT with other technologies:

- NT as basic technology in an industrialised agriculture and food processing
- GM (seeds, plants, food processing)
- ICT (sensors)

## 2.3 European Commission (2004): 'Nanotechnology – Innovation for tomorrow's world'.<sup>10</sup>

### **Summary**

The stated aim of this brochure is to “illustrate what nanotechnology is and what it can offer to the European citizens.”<sup>11</sup> It introduces nanotechnology and describes uses of “nanotechnology” in nature and then goes on to review possible areas of innovation through nanotechnology. There is very little discussion of the possible risks associated with the technology.

### **Key findings**

Nanotechnology offers enormous potential to improve European society and economies but... ‘If nanotechnology becomes part of everyday life, nothing would have to change dramatically on the outside’.<sup>12</sup>

“Nanotechnology is considered as the key technology of the 21st century. It can offer solutions to many current problems by means of smaller, lighter, faster and better performing materials, components and systems. Nanotechnology opens up new market opportunities and can also make some essential contributions to environmental and health protection.

“The aim of this brochure is to illustrate to the public what nanotechnology is and thereby to stimulate the discussion. By describing the scientific background, technological developments, areas of application, and potential developments of the future, this brochure provides a complex and comprehensive picture of nanotechnology as we see it in our days.”

The main usefulness of this document is in illustrating what nanotechnology is and the potential benefits to society. It is not providing a balanced analysis of the potential risks and opportunities.

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<sup>10</sup> European Commission (2004): Nanotechnology – Innovation for tomorrow's world, European Commission, Directorate General Research – Nanoscience and Nanotechnology, Bruxelles 2004  
Initially published in German as ‘Nanotechnologie – Innovationen für die Welt von morgen’, Bundesministerium für Bildung und Forschung, Berlin 2004

<sup>11</sup> Ibid, p.3

<sup>12</sup> Ibid, p.28

“Its German focus reveals that the book was originally created by the German Association of Engineers (VDI), through a project funded by the German Federal Ministry for Education and Research. Author Mathias Schulenburg is an experienced science journalist and writer on nanotechnology.”<sup>13</sup>

The initial research was carried out for the German Federal Ministry for Education & Research (BMBF).

### ***NT applications covered and related ELSA***

#### **Social**

Mobility can be improved through

- better safety from electronic monitoring;
- new coatings and paints
- the report even suggests possibility of ‘eternal motion machine’<sup>14</sup>
- Gold nanoparticles can be used in the prevention of odours.<sup>15</sup>
- There is a section on ‘Opportunities and risks’<sup>16</sup> which focuses on the ‘potential for good’ and scope for employing thousands and that ‘scientists and businessmen are unanimous that nanotech is more than just hype’. It dispels the myth of grey goo and reaffirms the safety and health benefits of sun cream stating that the ‘risks appear to be manageable... We already know of some nanoparticles that are not harmful to human health. They are therefore used in sun protection cream... Industry is also applying suitable safety measures in order to exclude any health risks to its customers or employees.’<sup>17</sup>

**Ethical:** This is not really covered further than opportunities and risks section above.

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<sup>13</sup> According to <http://www.cordis.lu/euroabstracts/en/august04/techno01.htm>

<sup>14</sup> Ibid, p.32

<sup>15</sup> Ibid p.32

<sup>16</sup> Ibid, p46-7

<sup>17</sup> Ibid, p47

**Legal:** Not covered in this document.

### **Environmental**

- LEDs can be used for more efficient lighting and in TVs.
- The 'simple' cleaning of drinking water using ceramic membranes with nanoscale porosity.
- Increases in efficiency and reduction in costs of solar power will make it a 'viable and lucrative' energy source.
- The use of nanotechnology to develop materials capable of thermoelectric energy generation
- Nanotechnology is enabling improvements in ceramic films, surfaces and catalysts to make more efficient fuel cells.

### **Health**

- Improvements in monitoring systems that can enable the development of 'functional food' i.e. sensing the lack of calcium in diet of shopper and recommending correct food.
- Nanoparticles already in use in sun cream and toothpaste have a positive benefit.
- Improvements in diagnosis and drug delivery.
- Improvements in cancer therapy including directing magnetic nanoscale particles to cancer sources.
- Miniaturising techniques to allow laboratories-on-a-chip apparently allowing scientists to eventually 'decode the mystery of life'.

There is some implicit reference to convergence with biotechnology and IT.

### ***Additional information, comments***

There is no discussion of the need for dialogue. The only reference to any communication between developers and accommodators of the technology is in the opening statement, which says it is designed to 'illustrate what nanotechnology is and what it can offer to the European citizens' (foreword). It appears that the brochure does not provide "a complex and comprehensive picture of nanotechnology" as suggested and a more balanced view would be need if the document were to be used for "stimulating discussion" or illustrating

“to the public what nanotechnology is”. In that it falls short of the goals on encouraging a dialogue for understanding potential impacts associated with nanotechnologies set out e.g. in the Commission’s Nanoscience and Nanotechnology Action Plan.<sup>18</sup>

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<sup>18</sup> Commission of the European Communities (2005): Communication from the Commission to the Council, the European Parliament and the Economic and Social Committee. Nanosciences and nanotechnologies: An action plan for Europe: 2005-2006.

## 2.4 Greenpeace Environmental Trust (2003): Future technologies, Today's Choices. Nanotechnology.<sup>19</sup>

### **Summary**

Greenpeace Environmental Trust provides a balanced review of the issues surrounding the developments in nanotechnology. The report includes an introduction to nanotechnology, the status of current research and development, and a review of applications, including useful tables with time to market. The report challenges the hype surrounding nanotechnology and discusses visionary applications. The discussion is set within the context of potential social and environmental risks.

### **Key findings**

Most contemporary experimental capabilities are in their infancy. Therefore it is difficult to foresee many of the outcomes. Initially the impact of nanotechnology will be limited to areas where there is a willingness to pay a premium for improved service. However, as tool and fabrication techniques improve we could start to see massive impact, perhaps in the 30-50yr timeframe. In meantime there are a number of concerns, mainly around human health. The report recommends that Government and Industry learn from the mismanagement of GM. Although an externally imposed nanotech moratorium seems both impractical and probably damaging, industry may find self imposed if it does not take acceptance seriously. Industry must demonstrate a commitment to this by funding relevant research.

It is always important to understand the Greenpeace position on issues such as nanotechnology as they are likely to be at the front end of any activist activity and raising public awareness of the environmental and social issues. This is a balanced report from Greenpeace and has been welcomed by some in the NT world as a good step towards a dialogue in the middle ground.

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<sup>19</sup> Greenpeace Environmental Trust (2003): Future technologies, Today's Choices. Nanotechnology, Artificial Intelligence and Robotics; A technical, political and institutional map of emerging technologies. Department of Environmental Science and Technology, Imperial College, London.

***NT applications covered and related ELSA***

The report has tables on areas of nanotech which include: properties, applications and timescale to market.

Applications mentioned:

1. Smart food wrapping for food etc
2. Improvements in catalysts
3. Advances in materials – nanotubes, quantum wells, quantum dots, Polymers, nanocapsules (e.g. C60), nanocoatings, nanocomposites, textiles.
4. Applications in Informatics including conductor manufacture to Quantum information processing (QIP) and molecular nanoelectronics. Photonic crystal technologies.
5. Convergence of biotechnology and nanotechnology: - genomics, bioinformatics etc
  - a. Diagnostics – molecular marking, Lab on a chip, Quantum dots
  - b. Drug delivery – nanoparticles, nanocapsules, nanoporous material, pharmacy on a chip, biomolecular sorting
  - c. Tissue regeneration and repair – nanoengineered prosthetics. Cellular manipulation
6. Energy – significant changes in lighting and PV
  - a. Power Generation – improvements in PV cells
  - b. Fuel conversion/storage – Catalysts, Nanotubes and nanoparticles.
7. Defence applications.
  - a. Nanoweaponry
  - b. Soldier kit
  - c. Advanced simulation
  - d. Information gathering
  - e. The potential to make weapons cleaner and safer?

**ELSA**

One of the greatest difficulties in predicting impacts of new technologies is that once the technical and commercial feasibility of the innovation is demonstrated, subsequent developments may be as much in hands of users as the innovators i.e. can be used in ways not intended.

**Environmental**

The key areas discussed are:

- Non-biodegradability of nanomaterials and the change in impact and nature of macro v. micro materials.
- Human health impacts. For example, concerns about the structural similarities between asbestos and nanotubes.
- The binding of nanomaterials to other pollutants to facilitate transfer into environment/food chain. The report highlights the lack of work done on impact of nanomaterials on living systems.

The report does raise the issue of self-replication and highlights that although this is unlikely/a long way off it is important to take into consideration.

**Socio/Political**

- Key to the discussion about the impact of nanotechnology is the disruptive nature of technology and possibility of a paradigm shift.
- The technology could have considerable impact in the area of medical ethics e.g.
  - Genomics and discrimination
  - Negative selection of characteristics
  - Enhancing human performance
- There is concern that nanotechnology may well exacerbate the digital divide and go further to create a 'Nano-divide'. Developments could further concentrate materials and information in the corporate domain and many countries may experience a painful transition from pre-nano to post-nano.
  - Privacy issues for pervasive computing
- The report highlights the potential destructive uses of nanotechnology including

- A potential nanotechnology arms race
- Production of 4th generation nuclear arms
- An increasing Nano-weaponry divide.
- Political acceptance of NT
  - Call for research into impact on mammalian systems
  - Advocates creation of dialogue
- Regulation
  - Accepts that it is impractical to have a moratorium. Instead all issues to be brought out into the open.
  - While higher order impacts of NT are unknown, the involvement of environmental and social scientists with correct regulation should allow NT to flourish while preventing wider impacts but concern about misuse and safety.

The report calls for immediate dialogue and a dramatic increase in research on the impact of nanotech on the environment and mammalian systems etc.

### ***Additional information, comments***

The report concludes that while an externally imposed moratorium would be unpractical and probably damaging at present the industry might find such a fate self-imposed if it does not take public acceptance seriously.

## 2.5 IOEW (2004): Effects of the production and use of nanotechnologies on sustainability.<sup>20</sup>

### Summary

This paper presents the results of a project addressing the effects of the production and use of nanotechnology (NT) on sustainability. The project was funded by the German Federal Ministry for Education and Research (BMBF) and carried out by the German Institute for Ecological Economy Research (IOEW).

### Key findings

The authors chose three approaches to provide information on NT and sustainability: (1) the prospect oriented approach, (2) the process evaluation approach and (3) the formative approach.

(1) “The prospect orientated approach has its focus on the evaluation of NT and its effects via a characterisation of the technology as a generalising approach to technology assessment”<sup>21</sup>.

(2) The process evaluation approach analyses four specific NT applications, namely NT lacquers; styrene synthesis; display devices; light sources identifies in terms of their sustainability effects. In doing so, the study compares new NT based applications with existing products by focusing on ecological risks and benefits. Resource efficiency improvements, to some extent by factor 5, are reported. In addition to these applications, a fifth study deals, in a more descriptive way, with the risk potentials of NT applications in general.

(3) Finally, “formative approaches for a sustainable nanotechnology are formulated through mission statements”.<sup>22</sup> NT road maps and dialogue processes addressing different actors such as government and business are presented.

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<sup>20</sup>Steinfeldt, M., von Gleich, A., Petschow, U. et al. (2004): Nachhaltigkeitseffekte durch Herstellung und Anwendung nanotechnologischer Produkte [Effects of the production and use of nanotechnologies on sustainability]. Schriftenreihe des IÖW 177/04. Berlin 2004.

<sup>21</sup> Ibid. abstract.

<sup>22</sup> Ibid. abstract.

Unlike most of the currently available studies, Nachhaltigkeitseffekte durch nanotechnologische Produkte presents a rather technical and quantitative evaluation for the ecological sustainability effects of new NT-products and/or –processes. However, due to this focus other sustainability aspects, such as ethical, legal and social aspects (ELSA), are only marginally covered. The study is published in German with only a short abstract available in English.

### **NT applications covered and related ELSA**

Applying a list of criteria that covered the technologies eco-efficiency potential, risk-/toxicity potential, readiness for market, market relevance, degree of innovation, spectrum of application and material turnover, four NT-applications were selected for an in-depth study.

The studies focus on the ecological sustainability potential of NT-products and/or –processes explains why primarily links between ecological risks and benefits and NT applications can be found, while other ELSA are rarely covered.

Opinions and expectations regarding the convergence of NT with other technologies are addressed in the subchapter “nanovisions and its risk assessment”. For the four applications specifically addressed in the study, the following key findings are presented:

#### **Eco-efficient NT coatings**

- The case study claims that for all emissions and environmental impacts covered by the study, significant eco-efficiency potentials can be realised when substituting traditional with NT coatings. Thanks to a reduced coating thickness, resource efficiency gains can also be realised. This holds particularly true for the automotive-, airplane- and railway industries
- Specific risks in the field of NT lacquers are not mentioned.

#### **Catalysis applications in the styrol synthesis**

- Taking the example of nanotube based catalytic converters, energy efficiency gains in the synthesis of styrol of up to 50% seem to be achievable. From a life-cycle perspective this would represent energy savings of about 8 to 9%.
- In addition, the new catalytic converter design would allow a significant reduction in emissions of heavy metals.

- The potential risk associated with the use of nanotubes are mentioned in general, but not discussed in detail. The authors call for further and deeper research.

### **Display devices**

- Aiming at identifying potential eco-efficiency gains of NT-based display devices the case study concludes, that quantifiable estimates are currently not possible. If the emerging efficiency gains in the production of e.g. OLEDs can be realised, so the authors, display devices based on these technology are likely to be more eco-efficient. This statement is based on the assumption, that the production phase is getting an increasingly important role for the overall environmental performance of these products.
- Specific risks in the field of NT display devices are not expected.

### **Illumination products**

- Looking at the energy-efficiency potential of NT-based illumination products, in particular white LEDs, the study finds an efficiency improvement compared to traditional light bulbs but an decrease up to a factor of 3 compared to energy saving bulbs.
- Future developments, both in the area of with LEDs but also based on quantum-dots are expected to increase the efficiency potential of NT-based illumination products.
- Specific risks in the field of NT light sources are not mentioned.

### **General**

- In a fifth case study titled “risk potentials of nanotechnology based applications”, the authors discuss in some detail the risk potential of nanoparticles, talking the example of titanium oxide in sunscreen. They concluded that some experts question the safety of the products and that more research is needed both with regard to human health as well as to impacts on the environment.
- From a life-cycle perspective of nanomaterials in general the authors concluded, that while production processes and NT products per se are seen as relative safe, many issues regarding the disposal, recycling and accidental release of nanomaterials/nanoparticles are still unanswered.

***Additional information, comments***

Following up on what has been discussed, the study concludes in the two final chapters by discussing approaches that could help developing a sustainable nanotechnology and the role of specific actors to achieve this. Finally an outlook and actions to be taken are given.

## 2.6 IOEW (2004): Nanotechnology and Regulation within the framework of the Precautionary Principle.<sup>23</sup>

### **Summary**

The report gives an overview on the subject of regulating nanotechnology, analysing the state of the art in *existing regulatory frameworks for chemical substances*. The precautionary principle is introduced as a concept to take action in policy-making under conditions of uncertainty. The report also presents the latest research results on the possible hazardous effects of nanotechnology applications. Finally a number of recommendations for future policy design were presented.

### **Key findings**

There is a broad discussion about the precautionary principle in regulation. According to the authors existing regulations might be able to capture potential adverse effects of nanotechnologies but existing regulatory frameworks for chemical substances do not consider particle size. Including the particle size into the declaration duty for chemical substances (REACH) could be considered.

Addressing to the producer of nano particles the authors state:

- Large production volumes of nano particles should require risk analysis and risk management including collection of (eco-) toxicological data.
- Development of technologies should follow the guiding principle 'inherently safe nanotechnology'.
- Integration of safety, health and environmental aspects into corporate quality management.

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<sup>23</sup>Haum R., Petschow U., Steinfeldt M. (2004): Nanotechnology and Regulation within the framework of the Precautionary Principle. Institut für ökologische Wirtschaftsforschung, Berlin.

***NT applications covered and related ELSA*****Legal**

- Regulatory frameworks should orient towards the Precautionary Principle.
- Despite of gaps in existing regulation regarding the re-manufacturing of existing substances to nano-size new regulatory regimes are not yet necessary.

**Environment, health**

- Risk analysis and risk management including collection of (eco) toxicological data.

***Additional information, comments***

- Study refers to public debate in various countries.
- Focus on legal aspects (PP) – does not investigate the wider societal/ethical implications.
- The study is very cautious in terms of suggestion possible measures.

## 2.7 komm.passion (2004): Wissen und Einstellung zur Nanotechnologie.<sup>24</sup>

### *Summary*

“Wissen und Einstellung zur Nanotechnology” is a representative study on the German population’s knowledge about and attitude towards nanotechnology. By means of face-to-face interviews more than 1000 randomly selected person from all across Germany have been interviewed.

### *Key findings*

The study shows, that nanotechnology (NT) is still very little known in the general population. About half of the population is unfamiliar with the term NT, an additional third has heard about it, without knowing any specifics and only a sixth part is able to specify some details, such as e.g. the scale at which NT operates, certain application areas or the fact that NT is seen as the next industrial breakthrough technology.

From those who knew some details about NT, none mentioned negative aspects of NT, which indicates that NT is so far primarily known by the “technophile” part of society. Compared to other key-technologies, namely genetic engineering, nuclear technology and combustion technologies, the level of information on NT is by far the lowest, according to the study.

When it comes to the current perception of risk the different technologies constitute on mankind an environment, nuclear technology and genetic engineering rank far higher than combustion technologies and NT. The study also shows, that the general public hasn’t made up their mind yet (a third is undetermined), and that the perception of risks decreases with the level of knowledge about the technology.

Following the risk perception, the study looks at expectations, hopes and fears connected to NT. For example while more than half of the population tends to have positive expectations when it comes to NT’s

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<sup>24</sup>komm.passion (2004): Wissen und Einstellung zur Nanotechnologie – Höchste Zeit die Weichen zu stellen [Knowledge about and attitude towards nanotechnology – It’s high time to set the course]. A representative study by komm.passion GmbH, November 2004.

potential to improve the daily life, the majority also expects companies to use NT in an irresponsible manner.

Concluding on the findings, the study puts forward five theses for a better communication of NT, stressing e.g. the importance of trust on the information that is provided, calling for NT labelling as well as highlighting the importance for all stakeholders to develop short-, medium- and long-term communication strategies.

While “Wissen und Einstellungen zur Nanotechnology” is not a study specifically addressing ethical, legal and social aspects (ELSA), it provides a representative insight in the general public's current perception of NT and its potential risks and benefits. In that sense it will prove to be a useful input for any kind of dialogue on the opportunities and risks of nanotechnologies.

komm.passion is a German communication agency focusing on health-, corporate-, issues & crisis- as well as financial communications.

### ***NT applications covered and related ELSA***

The study at hand looks at the general public's current perception on risks and chances related to NT. In doing this, it does not discuss in detail ELSA of NT. While convergence of technologies is not discussed, the comparison in the risk perception of different key technologies, as mentioned above, is covered.

When it comes to specific application areas, about two thirds of the population would be supportive to NT if it brings advancements in the **medical sector**. Support in similar magnitudes can be expected if advancements in the areas of **environmental protection** and **energy savings** can be developed.

With regard to **consumer protection**, 60% are supportive to the idea of labelling NT products and more than 50% would like to see more information on the potential side effects of NT. Almost 70% of the population feel a lack of information on NT in general and call for an independent, public funded research on the chances and risks. It thus doesn't come as a surprise that about two-thirds support a strong governmental role in controlling NT.

While a general level of distrust in the companies' responsible conduct with the technology can be observed (about 50% would agree that “there is a risk that companies use NT in a irresponsible

manner”), almost two-thirds view NT as important for economic growth.

***Additional information, comments***

Concluding from the above, the authors outlined 5 theses for communicating on NT:

1. Trust is most important. The debate on nuclear energy and genetic engineering got lost because the general public lost the trust in key accommodators such as the state and businesses. Being transparent and consistent in terms of talking and acting seem to be a key in the upcoming discussion on NT.
2. Balance of ratio and emotion. While the discussion should be based on scientific evidence, it is important to keep the emotional perception of NT in focus.
3. Labelling. For increasing the transparency, labelling NT products prior to first potential scandals seems important.
4. Good and evil NT. A clear distinction between the current NT applications and future molecular manufacturing also with regard to the terminology seems useful.
5. Discussion cannot be fully controlled. Knowing that a hundred percent control of the discussion on NT is an illusion, all stakeholders are recommended to develop short-, medium- and long-term communication strategies.

## 2.8 Meridian Institute (2005): Nanotechnology and the Poor.<sup>25</sup>

### **Summary**

Nanotechnology and the Poor's intention is to raise interest and awareness about the implications of nanotechnology (NT) for poor people in developing countries. It describes possible opportunities and risks posed by NT for poor people, without taking sides in the discussion. In doing so a focal point of the study is the potential of NT to contribute to the achievement of United Nations Millennium Development Goals (UN MDGs).

### **Key findings**

Following the opportunities and risks section, the authors explore the potential roles and responsibilities of various stakeholders in linking NT and poor people/developing countries, such as governments and academia role to stimulate and engage in North-South research cooperation's.

In the last chapter the authors call for "upstream engagement" at an early stage. Shaping the direction of NT research in a manner that helps to meet the needs of the poor, improving the research and risk transparency and connecting actors of different sectors are described as the next steps.

The study's author, the Meridian Institute, describes itself as a US based "non-profit organization whose mission is to help people solve problems and make informed decisions on complex and controversial issues".<sup>26</sup>

Nanotechnology and the Poor provides a brief overview on the opportunities and risks connected to NT applications with a special emphasis to developing countries and issues linked to a possible nano-divide. Without going into any detail, the report links findings from a rich source of studies and interviews to global sustainability questions, expressed in the UN MDGs. It thus can serve as a brief but condensed basis to raise awareness and stimulate discussion on

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<sup>25</sup> Meridian Institute (2005): NANOTECHNOLOGY and the POOR: OPPORTUNITIES and RISKS. Closing the gaps within and between Sectors of Society. Washington DC, 2005.

<sup>26</sup> Ibid, p. i.

NT opportunities and risks in general as well as with regard to the developing countries.

### ***NT applications covered and related ELSA***

What role can NT play for achieving the UN MDGs and what are social and ethical opportunities and risk connected to this is the central reference point of the study. Examples for the convergence of technologies, such as biotechnology or information- and communication technology based NT applications are mentioned, but not discussed in detail. Examples are given on how NT could benefit the poor but also on its possible threats for a range of NT applications.

#### **Energy**

- NT is seen as technology allowing for the cheap production of solar powered electricity and energy storage systems. Improved performance of rechargeable batteries, high-efficiency, flexible and light-weight solar cells and even solar power film paints are mentioned as a future technology enabling the access to basic and clean energy services Thus it is seen as a contribution to the alleviation of poverty and to environmental improvements.
- Specific risks in the field of energy applications are not mentioned.

#### **Health and water**

- In general, NT is seen as a technology offering possibilities for health breakthroughs, yet many of them seem to be high-tech and thus quite costly, and the authors claim that “it is hard to imagine their being used as health interventions among the poor<sup>27</sup>”.
- On the one hand, various NT applications in the health sector are expected to enhance medical care. One of NT’s most immediate and compelling promise in this respect is seen in the access to safe drinking water via NT based filter systems. Developers claim that not only bacteria and viruses, but also even compounds such as lead, arsenic and uranium can be filtered out of the water.

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<sup>27</sup> Ibid, p. 7.

- Next to water, disease treatment are mentioned, e.g. gels that could reduce HIV infection in women; simple, accurate, small and stable diagnostic test units or improved drug delivery using new NT membranes.
- On the other hand risks of NT applications on human health are described for various applications. Since they are not specifically mentioned for the health sector, details are provided in the general section below.
- Moreover the study briefly addresses the role of NT in enhancing human performance in a critical way.

### **Information and Communication Technology (ICT)**

- Without stating any specific examples or details, the report claims, that NT can play a positive role in helping society to achieve the MDG in the areas of education and poverty alleviation by providing cheaper and faster ICT technologies. Poor people become more competitive and better educated by possessing ICT products and access to worldwide information.
- The unknown environmental effects caused by nanoparticles used in computers etc. is one risk mentioned in course of ICT NT applications. The authors stress unanswered questions about persistence or toxicity of nanoparticles as well as NT monitoring devices that, because of their size, could be both ubiquitous and invisible.

### **Food and Agriculture**

- Several studies suggest that NT will have major, long-term effects on agriculture and food production, but it remains unclear whether the effect for developing countries will be positive or negative.
- NT may help making agriculture and food production more efficient, cheaper and more sustainable (e.g. wasting less water and chemicals) with help of advancements similar to those promised in drug delivery and human medicine. Examples are molecular manufacturing and design; time-controlled release of substances; remotely regulated, pre-programmed, or self-regulated delivery of nutrients or disease treatments; transplanted cells protected by membranes; bio-separation; rapid sampling and diagnosis of plant or animal health.

- As for the socioeconomic questions, the study mentions that if the developed countries use NT to produce food more economically, they will become less depended on agricultural raw products from developing countries, with potential negative socioeconomic effects.
- A risk already mentioned in the health and ICT sector is the effect of nanoparticles or nanoproducts on human health, animals and the environment.

### General

- A general problem addressed is the lack of adequate regulatory systems in developing countries. Especially managing complex technologies like NT could become a severe problem (e.g. inappropriate environmental, human health, and worker safety regulations).
- As for the risks of NT applications on human health and the environment, contradicting evidence is reported. Opinions range from statements such as “we have manipulated matter at the nanoscale for many years, and the risks of NT are simply more or the same, not different”<sup>28</sup> to those arguing that “manipulating matter at a scale where quantum mechanics begins to operate is completely new to human experience”<sup>29</sup> and that we therefore “know little or nothing about how these tiny new constructs are going to interact with living cells”<sup>30</sup>. Nanoparticles that exist in nature tend to clump together, while many commercially produced Nanoparticles are treated so that they don’t. Questions such as the persistence of NT particles, their accumulation potential in fat tissue and first reports on the likelihood to breaching the barrier protecting animal’s brains and central nervous systems are also raised.
- As already mentioned for the health and agricultural applications, the report raises questions on the socioeconomic implications of NT. Will it further marginalise the poor due to a lack of capacities, resources or the loss of markets for raw materials?

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<sup>28</sup> Ibid, p. 8.

<sup>29</sup> Ibid, p. 8.

<sup>30</sup> Ibid, p. 8.

- Also concerns that intellectual property rights controlled by developed countries and multinational corporations is briefly mentioned, leading to a widening NT gap between the North and the South.

### ***Additional information, comments***

- Concerns are voiced over the lack of standard risk assessment procedures for NT materials and applications.
- Those stating that manipulating matter at a scale where quantum mechanics begins to operate is completely new to human experience and that “we know little or nothing about how these tiny new constructs are going to interact with living cells”<sup>31</sup> also claim that existing regulations, guidelines, norms, and ways of thinking may be mostly irrelevant to NT.
- At the end of the report, the role and responsibilities of government, business, academia and civil society to help realising the advancements of NT also for the poor are discussed. Governments and academia are asked to stimulate and engage in North-South research cooperation while businesses should further explore the potentials of “pro-poor business”. As for non-governmental organisations the authors call for development groups to better participate in the emerging nanotechnology debate in order to also explore the potential benefits of NT applications.
- Due to the fact that the development of new technologies tends to outpace the development of methods to ensure a more egalitarian sharing of its benefits or the analysis of its associated risks, the report calls for an “upstream engagement” involving NGOs, civil society, funding bodies etc. to ensure an early engagement of concerned groups with those doing the developing.
- As regards public dialogue it is stated that it is even harder to get information on NT to the public in the developing world than in the developed world.

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<sup>31</sup> Ibid, p.8.

## 2.9 Munich Re: Nanotechnology – What is in store for us? <sup>32</sup>

### **Summary**

The study provides an overview of the safety concerns related to nanotechnologies and how these can be described on the basis of the current state of the art. It concludes in stating what aspects an effective nanotechnology risk management should cover and who should be involved in managing and reducing safety concerns.

### **Key findings**

The report concludes that the risks of nanotechnologies lie in our ability to control it. At this stage insurances cannot provide accurate answers to the nano risk problem. Instead risk management tools designed to prevent and reduce losses need to be developed so that the third-party liability insurer covers only the residual risk. “However, what is even more important is to establish an ongoing dialogue between insurers and the manufacturers and consumers of nanotechnical products and procedures, so as to reduce the risk for all concerned<sup>33</sup>” .

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<sup>32</sup> Schmid G. (2002): Nanotechnology – What is in store for us? Munich Re, Munich, 2002. URL [http://www.munichre.com/publications/302-03534\\_en.pdf](http://www.munichre.com/publications/302-03534_en.pdf)

<sup>33</sup> Ibid, p. 15

The recommendations concerning nano risk management are summarised as follows<sup>34</sup>:

“Specifically, risk management should cover the following:

- Technological assessment and an appraisal of the effects of each nanotechnologically produced article.
- Differentiation between passive (e.g. passive surfaces) and active (e.g. robots in the human cell) nanotechnology products.
- Active nanotechnology manufacturing only under controlled, high security laboratory conditions (HPR approach).
- Use of active nanotechnology products with guaranteed, continuous monitoring.
- Lifecycle-monitoring obligation on the manufacturer and devising of recall strategies and technical options.
- Decoupling of function and power supply for active nanotechnology products.
- Compulsory tagging of products, which incorporate active and passive nano components.
- Setting up of discussion and decision-making organs on social, corporate, ethical and political levels, to give all interested parties a chance to voice an opinion.”

The study provides brief, but condensed insights of the insurance industry’s perspective and clarifies how current liability concepts can be applied to nano applications. This makes it useful for assessing legal implications of nanotechnologies with regard to product risk insurances.

Author Dr. Gerhard Schmid is Head of Casualty Risk Consulting at Munich Re, Germany; further information about the co-authors Clemens Zelaskowski and Dr. Joachim Haun is missing.

### ***NT applications covered and related ELSA***

Applications are mentioned exemplary in order to provide an overview of the vast area of products affected by nanotechnologies.

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<sup>34</sup> Ibid, p.15

Besides outlining risks concerning health and the environment the study focuses on legal/insurance aspects of nanotechnologies.

Product liability approaches related to nanotechnologies are categorised in passive nano products (such as surface coatings, powders or similar products, already manufactured using non-nanotechnology methods) and active nano products (those being able to act autonomously). On **passive nano products** the following present liability aspects/concepts can be applied: development errors, design errors, faulty manufacture, information errors, and product monitoring (that can be further divided into active product monitoring by the manufacturers or notification of defects to the manufacturer by consumers). While defects in **active nanotechnology products** may be caused by the factors referred to above, additional factors need to be considered due to the product's ability to move around in the environment independently (or even transform/replicate). These factors include aspects of: state of the art/reproducibility/programming, power supply, monitoring and retrievability.

Further legal/insurance aspects briefly discussed include product recall, public liability, environmental impairment liability, workers' compensation, medical malpractice, and motor third-party liability insurance.

### ***Additional information, comments***

Dialogue is seen as crucial for effective risk management: "However, what is even more important is to establish an ongoing dialogue between insurers and the manufacturers and consumers of nanotechnical products and procedures, so as to reduce the risk for all concerned."<sup>35</sup>

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<sup>35</sup> Ibid, p.15

## 2.10 Nanoforum.org (2004): Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology.<sup>36</sup>

### **Summary**

The report covers the present state of the art of the public and scientific debate on benefits, risks, and ethical, legal and social implications of nanotechnology in Europe and other parts of the world. There is an overview of research groups, funding programmes, projects and networks in Europe. It also reviews position papers of NGO's, Industrial associations and political parties already engaged in debate.

This is a good starting point for the subject thanks to a wide-ranging review of current activity (social, ethical and legal/ Benefits and risks) at a high level.

The report was written by the Nanoforum consortium, which comprises of leading European nanotechnology organisations led by the Institute of Nanotechnology (UK) and including VDI Technologiezentrum (Germany), CEA-LETI (France), CMP Cientifica (Spain), Nordic Nanotech (Denmark) and Malsch TechnoValuation (Netherlands).

### **NT applications covered and related ELSA**

The report covers a large range of applications and risks/benefits some of which are mentioned here.

The report contains an overview of current practice and possible future uses e.g. Nanotech in energy, life sciences and healthcare, automotive industry and mobility, ICT, chemistry and environment and consumer goods. Most of the information is at a very high level and briefly describes areas such as improvements in solar cells, tools for continuing the increase in transistor density e.g. nanoimprint Lithography, semiconductor devices.

- There is a summary of main initiatives and projects dealing with risk assessment of Nanotechnologies. E.g. NANOSAFE (FP5) – the risks of handling and use of nanoparticles.

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<sup>36</sup> Malsch I. (Ed.) (2004): Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology . (www.nanoforum.org) Multiple authors June 2004

- Potential impacts of nanotechnologies, and more precisely nanomaterials, are discussed and risks subdivided into Human health and environment. It makes distinction between nanomaterials from natural sources, combustion and those consciously engineered.

### **Health and Human impacts**

- There is an overview of work so far including animal studies e.g. Wyle Laboratories – carbon nanotubes and mice. Other studies are mentioned and an opinion given as to how reliable each of the studies is.
- The report highlights potential human risks and methods of exposure e.g. inhalation and ingestion, and points out that in a busy street each breath we take contains an average of 25million nanoparticles.
- The key to the issue is that these materials although inoffensive at macroscopic, they can be dangerous at nanoscopic.

### **Environment**

- The report covers the main potential impacts e.g. Bioaccumulation, Bio-toxicity and mutagenic effects and asks if nanomaterials be new form of non-biodegradable pollutants.
- Two key risks are presented. Primary is the invisible size of particle getting into environment/food chain, damage to plants and animals. Secondary is reactive nature of particles.
- CBEN is looking at behaviour of nanomaterials in atmosphere, hydrosphere and biosphere.
- There is also the mention of the impact of nanomaterials interacting i.e. there are two types of particles: nanoparticles alone (direct biological role) and nanoparticles in presence of metals (indirect role).
- The concern that nanomaterials might aggregate in the environment.
- There is also a discussion of risk methodologies for risk assessment.

The conclusion present is that at present there is no specific evidence that nanoparticles harm humans but the report calls for concerted effort into studies to confirm this.

### Social impact

- The issue that there is an increasing reliance on technology and to prevent us becoming slaves to this must have ethics code.
- Highlights the area of improving human performance through convergence of various technology and mentions a report by Roco and Bainbridge on the subject.<sup>37</sup>
- Analyses myths and scenarios presented in other literature.

### Ethics

The ethics section is divide into three sections – a) what are the risk b) how should this knowledge be shared c) how to achieve public acceptance and ensure access to NT is equitable.

Highlights three methods of stewardship:

- **Guardian** – ensures security and maintains the status quo. Such a system is governed by tradition, loyalty and authority and must be incorruptible.
- **Commercial** – ensures increased value through trade. Such a system is governed by negotiation, competition and industry and must be capable of adapting to new situations.
- **Information** – ensures increased knowledge through dissemination. Such a system is governed by honesty, cooperation and idealism and must be freely accessible to all.

Also covered under this section:

- The precautionary principle.
- The nano-divide
- Balance of power – government/civil society and commercial interest
- Human-machine interface
- Military use of NT

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<sup>37</sup>Roco, M. C., Bainbridge, S. B., Converging Technologies for Improving Human Performance: NANOTECHNOLOGY, BIOTECHNOLOGY, INFORMATION TECHNOLOGY AND COGNITIVE SCIENCE. National Science Foundation July 2002.

The report makes it clear that there are activities taking place to discuss issues but asks if they will take place at a suitable rate for full public understanding and negotiation of where developments should go. It also points out that there is a big difference between delivering information on ethics and engaging people in “ethics talk”

***Additional information, comments***

The report also includes a section on legislation section including positions from political parties and differences in national legislation. At present most countries just raising awareness of the issues.

There is a section on who's who in ELSA and Nanotech.

The report calls for:

- Call for much wider engagement and proper discussion of ethics.
- Call for proper research into human health impacts.

## 2.11 Paschen et al. (2004): Nanotechnologie. Forschung, Entwicklung, Anwendung.<sup>38</sup>

### **Summary**

The book is a general survey about Nanotechnologie and the current state of the art in research, development. Various applications in the industrial sectors automotive aviation, civil engineering, textiles, energy and chemistry are discussed. Special respect is given for the convergence of NT with information technology and biotechnology. The survey also takes a look on the R&D activities currently to be found in Germany.

### **Key findings**

#### **Generic**

New materials for chemistry, ICT, life science and medicine are highlighted as fields of application with high innovation potential. New materials are e.g. ceramics, coatings, tailor-made catalysts, and nanosurfaces. In the area of ICT nano-electronic devices are most relevant. In the area of life science the following applications are mentioned: lab on a chip, biosensors, drug delivery systems, nanomaterials for prostheses and implants, cosmetics and food.

#### **Chances and risk of nanotechnology**

Positive impact for health and environment: diagnosis and therapy methods, implants, human performance, resource efficiency, environmental remediation technology, energy capture and storage technology

Negative impact for health and environment: health/toxic effects, of nanoparticles (food additives, cosmetics, drug targeting), nanopollution.

#### **Ethical**

- Human enhancement (Cyborgs): Broader discussion about implications for human self-conception.

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<sup>38</sup> Paschen, H., Coenen, C., Fleischer, T., Grünwald, Oertel, D., Revermann, C. (2004): Nanotechnologie. Forschung, Entwicklung, Anwendung [Nanotechnology. Research, Development and Application]; Springer Verlag, Heidelberg 2004.

- Expand human life span by aging prevention and hide of aging.
- Shift in appreciation of the term “health” towards conformity with a cultural redefined concept of human well being. Pressure for adoption moral concepts of health.

### Legal

- Short overview over potential areas of regulation (national, Germany)

### Social

- Effects on individuals’ autonomy and self-determination in the social context (S 308ff).
- Main areas: privacy, nano-divide, public and national security,
- Risk-benefit distribution in society: need for risk assessment.
- International security: implications of the technological gap between OECD and other countries (asymmetry).

### ***NT applications covered and related ELSA***

- Human-machine interface (still visionary)
- Existing analogies to bio-, neuro-, IT-science
- NT applications in life science/IT (medicine/health): human-machine interface, human enhancement/performance
- Neuroimplants: Extensive control of body functions,<sup>39</sup> nanodrugs
- Nano-diagnosis/lab-on-a-Chip: data security/privacy, self determination

Study talks about the convergence of NT with other technologies:

NT in relation to life-sciences: Ethical implications of long term visions - replacement mankind by new life-forms.<sup>40</sup>

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<sup>39</sup> Ibid, p. 300

<sup>40</sup> Ibid, p.298

***Additional information, comments***

Broad information of the public is seen as a prerequisite of a rational societal debate on NT. A dialog between science, business and civil society on chances, risks, and perspectives is approved. This should help to identify applications with high market potential and benefits for society.

- Need for public information and education<sup>41</sup>; employees qualification,
- Funding of ELSA- and environmental research.
- NBIC/CT was not discussed in-depth, but this aspect is on the authors agenda.

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<sup>41</sup> Ibid. p.319

## 2.12 RAND (2001): The Global Technology Revolution.<sup>42</sup>

### **Summary**

The US based RAND Corporation is providing non-profit research that address the challenges facing the public and private sectors. In this study meta-trends as well as social, economic, political, and personal implications of interacting trends in biotechnology, materials technology, and nanotechnology were analysed. The overall (not nanotechnology specific) effects highlighted in the study are: significant improvements in human quality of life and life span, high rates of industrial turnover, lifetime worker training, continued globalization, reshuffling of wealth, cultural amalgamation or invasion with potential for increased tension and conflict, shifts in power from nation states to non-governmental organizations and individuals, mixed environmental effects, improvements in quality of life with accompanying prosperity and reduced tension, and the possibility of human eugenics and cloning.

### **Key findings**

Technology development is increasingly multidisciplinary and cross sectional. The simultaneous progress of multiple technologies and applications could result in additive or even synergistic effects. International competition on technological leadership correlates with investments in R&D.

### **Ethical**

The political or ethical implications of computing technologies are similar to those seen today. The trend of increasing human life spans in the developed world. Demographic shift and social consequences.

### **Legal**

Advances in technology could empower the proliferation of controlled processing capabilities (e.g., nuclear isotope separation) with associated threats to international security.

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<sup>42</sup> Anton, PS., Silbergliitt, R. & Schneider, J.: The Global Technology Revolution. Bio/Nano/Materials trends and their synergies with information technology by 2015. RAND-Report 2001, Santa Monica, CA.

Legislative debates concerning legal protections and regulations regarding intellectual property rights will emerge.

### **Social**

The pace of technological advance could make it more difficult for legal and ethical discussion to keep up with technology development. Societal and ethical concerns are accelerating as new technologies enable greater ability to manipulate the environment.

- Cultural effects: the way people interact and live is changing.
- Increased Need for Educational Breadth and Depth. Politicians and consumer need a wider understanding of science and technology to make informed decisions.
- Potential for reduced privacy.
- Continued globalization.

### ***NT applications covered and related ELSA***

35 nm gate length in **semiconductor technology** is expected to be reached in 2015, devices using carbon nanotubes as active elements.

**Quantum-Computing** and molecular electronics **are expected to be a potential long-term solution** in more and more powerful computing but not until 2015 – probably essential for cryptographic applications (related to privacy).

Integration of computational capabilities with biological, chemical, and optical components in systems-on-a-chip. Inexpensive and pervasive MEMS (**Integrated micro/nanosystems**) could economize current technologies while enabling new missions.

### ***Additional information, comments***

Study talks about the convergence of NT with other technologies:

Molecular manufacturing and Nanobots: no breakthrough until 2015 but integrated capability could be developed over the next 15 years.

## 2.13 Royal Society (2004): Nanoscience and nanotechnologies: opportunities and uncertainties.<sup>43</sup>

### **Summary**

The remit of the report was to define nanotechnology, summarise current scientific knowledge, look at current and future applications and identify health, safety, environmental, ethical and societal implications. The study was carried out by a working group composed of experts from the fields of science, engineering, social science and ethics.

### **Key findings**

NT/NS are already significant in metrology, electronics and ICT. It is likely to continue to be significant in these areas and has potential to affect nanomaterials, optoelectrics, biotechnology, medicine and industrial applications.

The report is well researched and well written with a clear and concise explanation of the issues. It raises and assesses many areas with balance and is willing to criticise hype and excessive pessimism equally. It provides a useful background to discussions on all aspects of Nanotechnology.

The authors, all based in the UK, are some of the UK's experts from different disciplines, from both within science and without. They include representatives of business, academia and civil society (both environmental and consumer organisations). The list of individuals who submitted evidence is broad, impressive, useful and takes in expertise from around the world.

### **NT applications covered and related ELSA**

The report is dedicated to addressing this area and can only be summarised here very briefly.

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<sup>43</sup> Royal Society/Royal Academy of Engineering, (2004): 'Nanoscience and nanotechnologies: opportunities and uncertainties', Report of the Royal Society/Royal Academy of Engineering Working Group.

**Social and ethical**

Current uses listed include: improved fabrics; paints using less solvent; cheaper, greater data storage; In the medium to long term: military battle suits and better water purification, increases in computer processing.

The main areas of concern are ownership and use of the technology. The report suggests that most ethical concerns are likely to arise in 5-15 years or 20+ years. Until then, convergence with ICT is likely to cause most pressing area of concern for parts of society are threats to civil liberties from surveillance enabled by nanotechnologies.

**Legal**

The report concentrates on intellectual property rights and regulation. Neither area is specific to any one application for NT. The former relates to concern about a 'nano-divide' over access to necessary beneficial technologies in future. The latter focuses largely on the need to review certain regulations to ensure potential toxicity of nanoparticles is dealt with appropriately.

Regulators (mainly in UK) are aware of the issues and are starting to address them. It is suggested that some cosmetic applications using nanotechnology should count as medicine as their impact on broken skin is unknown. The 'trigger' amounts for REACH ought to be reconsidered to take into account NT chemicals as some may slip beneath the trigger levels but have significant impacts. However, in the field of metrology, there need to be improvements in measurement and standards for satisfactory legislation to work.

**Health and environment**

Environmental:

Current uses with potential environmental benefits mentioned include: paints using less solvent; remediation of polluted land; more efficient fuel cells; energy efficient displays; more efficient batteries; fuel additives to improve fuel economy. In the Medium-long term: In the medium-long term: nanosensors in the environment – measuring quality of water, water purification.

**Health**

Current impacts from developments in sunscreens and cosmetics are discussed. The medium-long term developments include development of better medical implants, nanosensors and

laboratories-on-a-chip. The report looks into convergence of biotechnology on a timescale of 10+ years. Some of the areas mentioned: DNA nanomachines; detection of disease; drug delivery; drug discovery; non-invasive medical imaging; treatment for cancer; implants and prosthetics.

There are justifiable concerns raised, largely concerning the effect of non-fixed i.e. free nanoparticles and structures. Some chemicals, which are safe at normal levels, may become toxic at the nanoscale. For example, sun creams with nanoparticles of zinc oxide may be safe on normal skin, but there is insufficient research assessing the effect on broken/damaged skin. There is also the concern that some particles might be more combustible at the nanoscale. Overall the report recommends that far more research is urgently needed, particularly with regards to toxicology for humans and the impact on the natural environment.

### **Stakeholder dialogue and public dialogue**

Generally, public awareness of NT in UK is low so there is scope still to influence the public. However, members of the public have already expressed similar concerns to those raised with GM and nuclear. Dialogue is considered essential and to be encouraged immediately.

### ***Additional information, comments***

This report is the first of its kind. It was commissioned with a view to recommending to the UK government how it might react to concerns about NT. A whole chapter is dedicated to stakeholder dialogue and public dialogue, led by Dr. Nick Pidgeon, a leading social scientist with experience of running public dialogues on GMOs in the UK. It outlines existing thinking on public engagement on scientific issues, quoting Prof. Brian Wynne and colleagues extensively.

It provides additional information and research on a CD-Rom including the public attitudes survey by BMRB International, write-ups of workshops held with stakeholders and public and professional written submissions.

Convergence is discussed regularly, assuming that NT has to converge with other disciplines, most regularly ICT and biotech.

## 2.14 Swiss Re (2004): Nanotechnology - Small matter, many unknowns.<sup>44</sup>

### **Summary**

The Swiss Re report is a comprehensive risk analysis of nanotechnology as presently constituted, along with an overview of risks that might be associated with yet-to-be-developed materials. This report provides an introduction into the nanotechnology as well as the health and environmental effects that might emerge from the application of nanoparticulate matter.

... The publication concentrates on the fields of nanoparticle manufacture and material development. This may be a limited field, but it is the one that ought to interest the insurance industry most, as one day it might be relevant to the liability insurance. The focus is therefore on the products and applications that come into the human beings, or that may affect the environment."<sup>45</sup>

### **Key findings**

The re-insurance company express the concern over releasing nanoparticles which, because of their small size, are able to travel very far into the environment. They warn that we do not yet know how these particles will act in the environment or what chemical reactions they will trigger on meeting other particles. One of the chief issues is that, unlike other substances both natural and manmade, nanoscale particles have no difficulty penetrating the human body's blood-brain barrier. However the existence of nanoparticles does not necessarily pose a problem for people or the environment; a risk can only arise when the particles' properties turn out to be harmful. The report points out that "hardly any long-term or toxicological studies are currently available" and proceeds to discuss in great detail how the body absorbs and filters particles and how nanoscale materials defy these bodily processes.

Swiss Re warns that uncertainty about risks from nanotoxicity and nanopollution meant there was insufficient information to offer insurance on the industry. Swiss Re, is advising insurance companies

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<sup>44</sup> Hett, A. (2004). Nanotechnology - Small matter, many unknowns. Risk Perception. Zürich, Swiss Re: 57pp.

<sup>45</sup> Ibid, p.8

to think twice about their cover for products involving nanotechnology, until more is known about the possibility of side effects from the technology.

### ***NT applications covered and related ELSA***

The report's appendix lists a broad spectrum of ELSA relevant NT applications in the following areas:

- Diagnostics
- Drug delivery
- Tissue regeneration, growth and repair
- Power generation (PV technology)
- Fuel conversion/storage

Short information about properties, potential products and expected time-scale to market launch are also listed.

### **Nanotech in the environment**

Applications with potential environmental benefits mentioned include:<sup>46</sup>

Remediation of contaminated soil or water, decontamination of toxic exhaust fumes and other process-related secondary products, more efficient fuel cells; energy efficient displays; more efficient batteries; fuel additives to improve fuel economy. In the Medium-long term: In the medium-long term: nanosensors in the environment – measuring quality of water, water purification.

The report also discusses the adverse impact that nanoparticles could cause when released into the environment. Nanoparticles can be released into the water or the air and ultimately contaminate the soil and the groundwater. Further, many of the artificially manufactured nanoparticles will be new to the environment in type and quantity. They could constitute a completely new class of non-biodegradable pollutants, with which scientists, obviously, are still unfamiliar. The long-term behaviour of such substances and their effects on the elements are thus extremely hard to foresee.

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<sup>46</sup> Ibid, p.27

### **Occupational Health**

To date, the risk of work-related exposure to nanoparticulate substances is uncertain and only defined for exposure larger forms of particle. The author states that adequate dust respirators for nanoparticulate substances are not available.<sup>47</sup>

The exposure limits were set for much larger particles and are, in fact, too high for nanoparticles. Regulations governing the transport of nanoparticulate powders are not specifically mentioned.

### **Regulatory context**

Up until early 2004, nanotechnologically manufactured products were not subject to any special legislation. There were neither special regulation, recommendations on how such products or their base materials were to be handled, nor any obligation to label such products for what they were.<sup>48</sup>

The report highlights an internationally valid standardisation as essential. Without standardisation, even the labelling of products becomes an extremely difficult undertaking.

### **Stakeholder dialogue and public dialogue**

The report provides many suggestions, among these is a call for the industry to find a common terminology and nomenclature (presently different labs refer to the same nanoparticles by different terminologies and chemical shorthand).

Further Swiss Re is asking for an "open risk dialogue" involving scientists, industry, regulators, and the insurance sector.

Talking openly and responsibly about risks is the task of all those who possess the necessary knowledge and, above all, of those in the manufacturing industry. Dialogue is needed among science, industry, the authorities and the public. As the risk carrier, the insurer carries the responsibility for leading the risk dialogue, including with lawmakers.<sup>49</sup>

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<sup>47</sup> Ibid, p. 33

<sup>48</sup> Ibid, p.36

<sup>49</sup> Ibid, p.46

An adequate risk management is recommended for insurers. As the liability risk is incalculable, the insurer must calculate his commitment based on a worst-case loss scenario.

The report recommends the precautionary principle to be applied in case scientific uncertainties regarding the risks have not yet been finally clarified. In view of the dangers to society that could arise out of the establishment of nanotechnology, and given the uncertainty currently prevailing in scientific circles, the precautionary principle should be applied whatever the difficulties. The handling of nanotechnologically manufactured substances should be carefully assessed and accompanied by appropriate protective measures. This is particularly important for individuals whose jobs expose them to nanoparticles on a regular basis. At the same time, no reasonable expense should be spared clarifying the current uncertainties associated with nanotechnological risks.<sup>50</sup>

***Additional information, comments***

- Highly perceived in the media and public risk debate.
- The report is published in German as well as in English.

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<sup>50</sup> Ibid, p. 47

## 2.15 VDI Technologiezentrum (2004): Nanotechnologie als wirtschaftlicher Wachstumsmarkt.<sup>51</sup>

### Summary

The technology forecast study gives an overview over the business potential of nanotechnology. Presently available information about market volume and market relevance of nanotechnological products in Germany and worldwide were collected and analysed.

### Key findings

#### Generic

- Only little public available literature about applications that are in development, market forecasts correspond to different time horizons;
- No radical/revolutionary change in the market, rather an evolutionary development in the near future (2006), market forecast: exponential increase in 10 years;
- Main technological areas influenced by NT (2015) are: Chemistry/New materials (1), Life Sciences/medical engineering/health (2), ICT/Electronics (3), with some distance: environmental technology, energy technology, transport;
- Commercial availability of applications like: principles of self organization for mass production, self replication techniques, nanobiotechnological products for the healing of diseases or elimination of DNA-defects, molecular sized machines, nanoelectronics not before 2015 or later;
- Application areas were localized in the following industrial sectors: chemistry (nanomaterials, intermediates, nanosensors), automotive industry, electronics, optical industry and life sciences<sup>52</sup>.

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<sup>51</sup> VDI Technologiezentrum (2004): Nanotechnologie als wirtschaftlicher Wachstumsmarkt [Nanotechnology as an economic growth market]. Innovations- und Technikanalyse. VDI, In Kooperation mit: Deutsche Bank, Hochschule für Bankwirtschaft, ICMT GmbH. Düsseldorf 2004.

<sup>52</sup> Ibid, p. 197

**Legal**

- Regulation is not regarded as a central barrier against the diffusion of NT.

**NT applications covered and related ELSA**

- Covered by acceptance of NT<sup>53</sup> ;
- High expectations in the fields health, prevention, medical diagnosis and therapy, environmental loss elimination effects;
- Recently more “Hope and hype” than “risk” communication (e.g. toxic effects or uncontrolled release of NP);
- Lacking information and communication, deficient expertise might lead to low public acceptance and might become an innovation barrier for NT (Show stopper effect);
- Implicit relation to ELSA via employment market/qualification.

Convergence of NT with other technologies is a core issue of the study.

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<sup>53</sup> Ibid, p. 217

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