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of NANOTECHNOLOGY

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Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology

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- 1st Nanoforum General Report: “Nanotechnology helps solve the world’s energy problems”, first edition published in July 2003, updated in December 2003 and April 2004.
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Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology

Abstract

In this report, the Nanoforum consortium presents 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. It also gives an overview of relevant research groups, funding programmes, projects and networks in Europe. Finally it reviews position papers of NGO's, industrial associations and political parties, which are already participating in the emerging political debate on nanotechnology, as well as debates initiated by governments, the European Commission and parliaments, and gives access to media coverage of nanotechnology.

Nanotechnology is showing promising developments in many areas and may benefit our health and welfare. However, we should be aware of possible unwanted side-effects. Nanotechnology means new materials and components, which can be included in many different existing products or enable new products. Applications include sustainable energy, healthcare, cars, information and communication, and household products. The main concern is currently the health and environmental impact of small nanoparticles. Risk research is ongoing. In the public debate also long term scenarios and science fiction including nanorobots play a role, as well as ethical and social aspects of priorities in research such as military applications and the nanodivide between haves and have-nots. The political debate on regulating nanotechnology is just beginning.

Nanoforum is a thematic network funded by the European Commission, aiming to promote and raise the standard of nanotechnology activities throughout Europe. Nanoforum comprises a consortium of leading European nanotechnology organisations led by the Institute of Nanotechnology (UK) and including VDI Technologiezentrum (Germany), CEA-LETI (France), Nordic Nanotech (Denmark), Malsch TechnoValuation (Netherlands), METU (Turkey), Unipress (Poland), Sofia University (Bulgaria), BIT (Austria) and NanoNed (The Netherlands). Nanoforum is an information source for the European Community that unites disciplines and countries. Nanoforum provides a resource for business, research, government and financial institutions across Europe. This report has first been published end of June 2004 on www.nanoforum.org . This update has been published in October 2005.

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Part 1: Executive Summary.

This report is intended for non-experts in risk analysis and in technology assessment, or ethical, legal and social aspects of nanotechnology, to get a quick insight in what these areas of research have to say about nanotechnology. It also includes an overview of the emerging political and public debate on nanotechnology in Europe. The Nanoforum consortium hopes this will be interesting to the following user groups:

- 1) Nanotechnology researchers interested in international collaborations with experts in risk analysis and the ethical, legal and social aspects of nanotechnology;
- 2) Experts in risk analysis and technology assessment interested in issues related to nanotechnology;
- 3) Politicians, NGO's and lay persons interested in what nanotechnology may mean for society.

This report includes parts on potential risks and benefits of nanotechnology; on public perception; on ethical and political aspects; and on the current status of the debate on legislation for nanotechnology. It also includes a list of European research organisations active in risk research specific for nanomaterials, and in ethical, legal and social aspects of nanotechnology. A continuously updated list of these organisations can also be found in the online database of institutions accessible at www.nanoforum.org. No glossary is included in this report, but readers who are unfamiliar with nanotechnology can check the online glossary at www.nanoforum.org.

What is nanotechnology?

In microelectronics, energy technology and biomedicine, some of the most crucial technological needs of today are related to nanotechnology. For example we would like to have more compact high-capacity lightweight batteries, more efficient solar energy technologies, less expensive high-resolution flat panel displays and more efficient means to transport drug molecules to targeted cells. Solutions to these problems are likely to be based on methods that border on nanotechnology.

Nanotechnology describes the creation and utilisation of functional materials, devices and systems with novel functions and properties that are based either on geometrical size or on material-specific peculiarities of nano-structures. Purely geometrically, the prefix "nano"

(Greek: dwarf) describes a scale 1000 times smaller than that of current elements of the micrometer-sphere (1nm corresponds to the millionth part of a mm). This scale has become accessible both by application of new physical instruments and procedures, and by further diminution of current microsystems. In addition, structures of animated and non-animated nature have been used as models for self-organising matter. Only if the mastery of this atomic and molecular dimension succeeds, can the prerequisites for the optimisation of product properties within socioeconomic areas such as energy engineering, environmental technology as well as in information technology, health and ageing be developed.

The world-wide industrial conquest of nanoscale dimensions began with the discovery of techniques to organise, characterise, and manipulate individual elements of matter as well as increasing insights into the self-organisation principles of these elements. In the meantime the speed of innovation has led to the situation that physical fundamentals are still being investigated while first product groups are already entering the world markets. Their sales impacts are caused by the implementation of nanoscale architecture with new macroscopic functions.¹

This report

In this report, the Nanoforum consortium presents the current state of the European and global debate on risks, benefits, ethical legal and social aspects of nanotechnology in October 2005. We have also included an overview of the government related, research, political and non-governmental organisations which are taking part in this debate, and of which we are aware. We would appreciate to be informed of other relevant organisations and news to be included in future updates of this report, and welcome your contribution. Please contact mark@nano.org.uk

Part 2 discusses the potential benefits of nanotechnology in the application areas of energy, life sciences and health care, automotive industry and mobility, ICT, chemistry and environment and consumer goods. We present benefits of nanotechnology which are already available or are expected in the next decade or so. We conclude that nanotechnology can lead to improvements of a wide range of products and technologies. Nanomaterials, coatings etc. can be applied in new and more sustainable energy storage, conversion and saving technologies. Biocompatible materials and other nanotechnologies will also be used in tissue

engineering, implants, diagnostics and drug delivery. The automotive industry is already and will be a large market for nanomaterials, sensors etc. In ICT, nanoelectronics is already part of the international technology roadmap of the Semiconductor Industry. Nanotechnology will be taken up in computer CPU's and memories. Nanomaterials will also lead to innovation in the chemical industry, and nanotechnology can contribute to environmental technologies including sensors and air, soil and water cleaning technologies. Nanotechnology can also become part of consumer goods for example in 'smart textiles'.

The risks covered in part 3 of this report are subdivided into human health and environment. Health impacts of nanoparticles currently under investigation include risks of lung and heart diseases from inhaled nanoparticles, accumulation of non-biodegradable nanoparticles in the liver and uptake into the brain. Nanoparticles may also enter the food chain. These can be either existing particles such as soot (a product of burning coal or wood), or manufactured nanoparticles which are present in consumer goods and could be released in the environment during or after the use of the goods. We present the current state of research on risks for health and environment of nanoparticles. This is now the most pressing issue in the political debate on nanotechnology. We conclude that at the moment, research on health and environmental impacts is ongoing. So far, there is no significant evidence that nanoparticles present risks for humans, but it should be noted that no sufficient proof could be collected yet. Studies should continue.

In part 4, public perception of nanotechnology is explored, as this will influence the acceptance and hence market chances of nanotechnology. Public perception is influenced by many factors including published scenarios of nanotechnology's long-term impacts on society. In this part, we discuss these scenarios from the perspectives of proponents and opponents of nanotechnology, including science fiction writers. These long term scenarios are not very relevant to the present day risks, benefits, and ethical, legal and social implications of nanotechnology. However, they do influence how the general public reacts to nanotechnology. These scenarios should therefore realistically be taken into account in a public debate on nanotechnology.

In part 5, we discuss current ethical aspects and political implications of nanotechnology. After an explanation of different ethical systems relevant to nanotechnology, this part reviews some ethical considerations of nanotechnology, including the risks debate, sharing knowledge

and public acceptance of nanotechnology. Nanotechnology is already the subject of public debate and social science research in the EU and some other countries, because politicians and industrialists have learned from the public opposition against GMO¹ food and other recent debates about new technologies. We analyse the present state of the global debate on ethical aspects and political implications of nanotechnology. We base this on an analytical framework of three types of ethical systems, borrowed from Chris Phoenix: guardian, commercial and information. We conclude that nanotechnology should be managed using all three types of ethical systems.

Part 6 consists of four contributions by social and human scientists and stakeholders on ethical and societal aspects of nanotechnology.

Part 7 discusses the need for new legislation for nanotechnology. This includes recent initiatives to standardise and test nanotechnologies, EU actions and directives which are relevant to nanotechnology and the positions of different lobby groups and parties on nanotechnology. It is clear that the discussion on whether or not nanotechnology leads to a need for new legislation is only just beginning. Issues include safety of nanoparticles, boundaries between laws governing market introduction of different kinds of technologies, military applications of nanotechnology, patenting and standardisation. It is too early to say what the outcome of these debates will be.

Research institutes in risk analysis and technology assessment in Europe dealing with nanotechnology, and lobby groups and political organisations which have already shown interest in nanotechnology and society are listed in part 8 and included in the database of institutions on www.nanoforum.org. The database will be continuously updated.

What's new in the October 2005 version?

Totally new is part 6, which comprises a debate forum on ethical and societal implications of nanotechnology. This part consists of four invited contributions from external authors. Two of

¹ Genetically Modified Organisms. The introduction of genetically modified food such as corn, soy beans or food crops which are resistant to pesticides or include terminator genes has been confronted with public resistance, especially in Europe. This has slowed the development of a European biotechnology industry, and increased awareness among policy makers, industry and researchers of the need for public debate about new technology in early phases of development.

these authors are experts in ethics and social science and have resubmitted articles which have been published elsewhere on ethics and nanotechnology. These experts are Professor Jean-Pierre Dupuy of Ecole Polytechnique, Paris and Stanford University, USA and Professor Armin Grunwald of TAB and ITAS in Germany. Jean-Pierre Dupuy's contribution looks at: "Complexity and Uncertainty; A prudential approach to Nanotechnology" (published as A contribution to the work in progress of the "Foresighting the New Technology Wave" High-Level Expert Group, European Commission, Brussels.) Armin Grunwald discusses: "Nanotechnology – A New Field of Ethical Inquiry?" (published in *Science and Engineering Ethics* (2005) **11**, 187-201)

The other two authors represent stakeholder groups to Nanotechnology, and write about ethical and societal aspects of nanotechnology from their viewpoint. These are Dr Douglas Parr of Greenpeace UK and Professor Sylvia Speller from the Radboud University in Nijmegen, The Netherlands (a Physicist). Douglas Parr submitted a preprint version of the article "Will Nanotechnology make the world a better place?" published in *Trends in Biotechnology* Vol.23 No.8, August 2005, pp.395-398, and Sylvia Speller submitted "From science fiction to science fact – a nano-scientist's views on the current debate on nanotechnology", as original peer reviewed work.

By publishing these contributions, Nanoforum hopes to open up the debate on these issues on our website. Peer reviewed contributions from other invited authors will also be published here in the future. We are also open to suggestions for authors.

Other changes to the 2005 edition of the Nanoforum report on Benefits, Risks, Ethical, Legal and Social Implications of Nanotechnology are in Part 2. These consist of minor changes to the paragraph on Information and Communication. Part 3 is also updated, including results of health and environmental risk studies on nanotechnology published between June 2004 and September 2005. The conclusion, that there is not enough evidence to decide if nanoparticles present a risk to humans or the environment remains the same. Toxicology and environmental impact research should continue. Part 7 (formerly 6) is also updated and includes information on international and national activities on regulation and standardisation of nanotechnology which have taken place since June 2004. New since the first version are public debate on nanotechnology in France and Belgium, the activities of the OECD Chemicals Committee, the installation of nanotechnology standardisation committees by ISO and CEN and work on nanopatenting classifications by EPO and other patent bureaus. We also include information

on new events and publications of the EU, countries and relevant organisations which were already active on nanotechnology regulation and standardisation before June 2004.

Parts 4, 5 and 8 have not been updated. We have decided not to update parts 4 and 5 on public debate and ethics as these chapters present merely one perspective to the broad spectre of viewpoints which are currently being discussed. We therefore opened the debate forum for invited authors in Part 6 to facilitate the exchange of visions. Part 8 is not updated, but instead we are continuously including more groups with expertise in social and economic studies of science, humanities and standardisation in universities and research organisation in our online database of organisations at www.nanoforum.org.

ⁱ www.nanoforum.org