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Nanotechnology as a Matter of TA
On expansions, reductions and distractions

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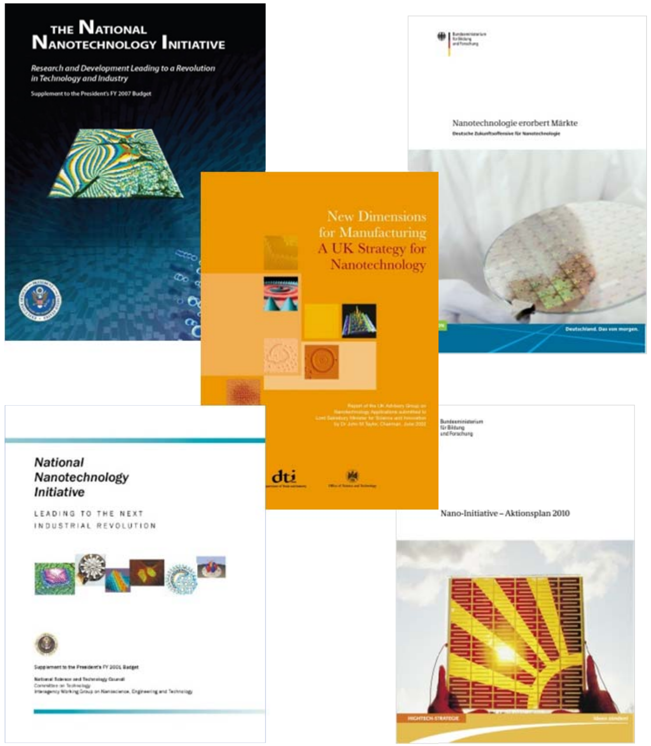
Nanotechnology in S&T Policy

- Upcoming topic in S&T planning and funding strategies since the end of the 1990s (esp. US, DE, GB, EU)
- large initiatives (e.g. National Nanotechnology Initiative of the President of the U.S., European Nanotechnology Strategy 2005) with big budgets



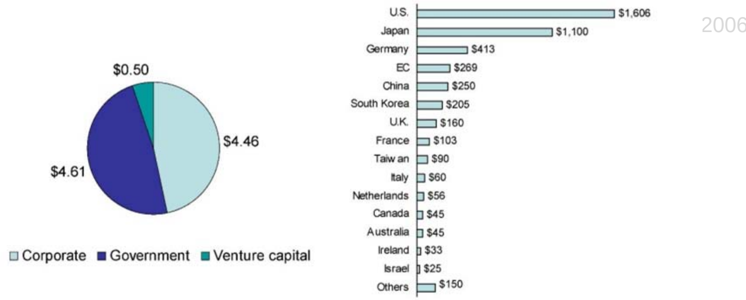
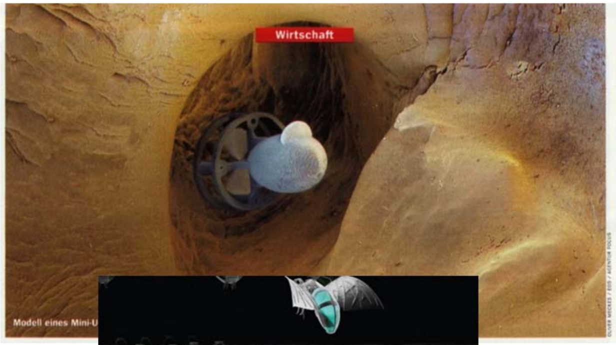
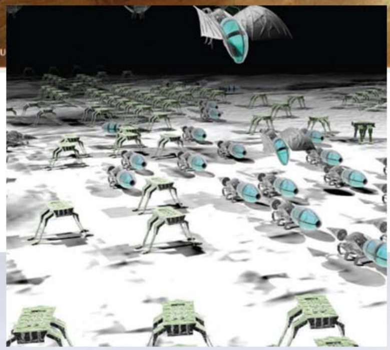


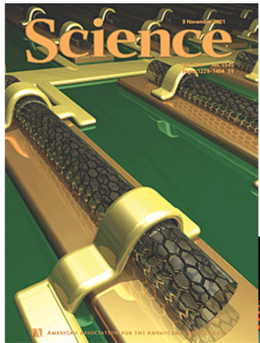
FIGURE 2-1 World nanotechnology funding, 2005. (left) Nanotechnology funding globally by source, 2005 (US$ billions). (right) Government nanotechnology funding by country, 2005 (US$ millions).
SOURCE: Lux Research, Inc., 2006, *The Nanotech Report*, 4th Edition. New York: Lux Research, Inc.

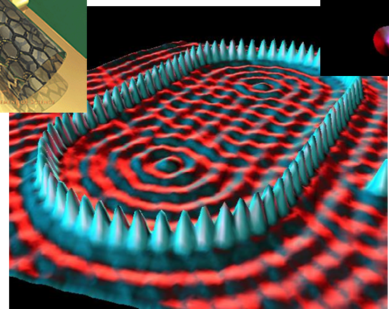
Nanotechnologies and Media

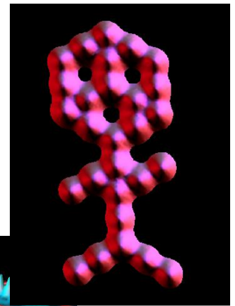
- Attention of media (Ambivalent descriptions and positions)
- Adaptation in (popular) arts (science fiction literature, movies, new technologies for digital visualizations)

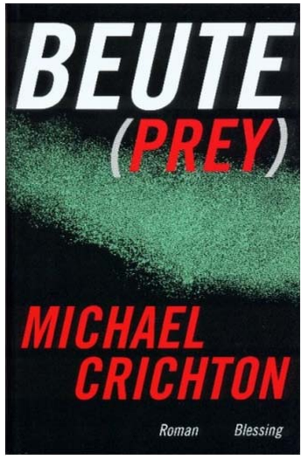






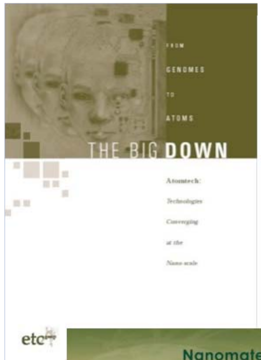




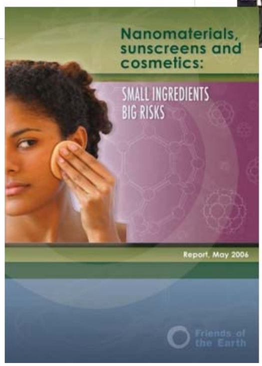


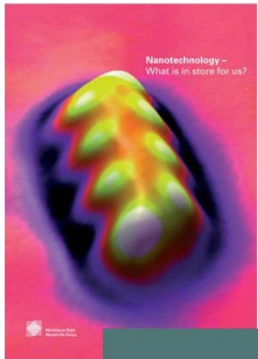
NT and Societal Groups

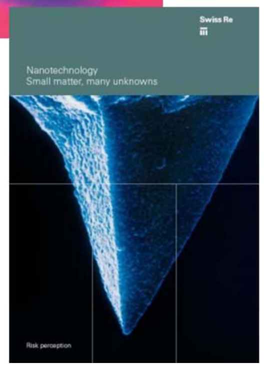
- Attention and Observation by CSO: Greenpeace UK, etc Group, BUND, FoE AU
- Third party economic actors (insurance companies), regulators
- Strong interest of TA (comprehensive report of TAB 2003), ELSI- (ethical, legal, social implications) and PUS- (Public Understanding of Science) Scholars

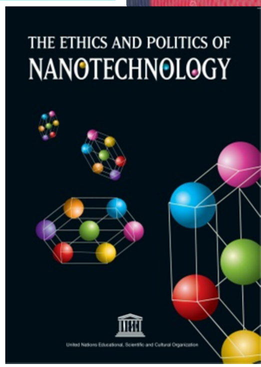


THONG, Chicago 2005









Nanotechnology – Consumer Products

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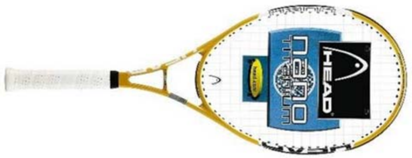

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Nanotechnology – Definitions

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Nanotechnology is the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with new or vastly different properties. (EP 2006)

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling and manipulating matter at this length scale. (NNI 2007)

The term 'nanotechnology' will be used here as a collective term, encompassing the various branches of nanosciences and nanotechnologies. Conceptually, nanotechnology refers to science and technology at the nano-scale of atoms and molecules, and to the scientific principles and new properties that can be understood and mastered when operating in this domain. (CEC 2004)

1. Definition of Nanotechnology

The essence of nanotechnology is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization. Compared to the behavior of isolated molecules of about 1 nm (10^{-9} m) or of bulk materials, behavior of structural features in the range of about 10^{-9} to 10^{-7} m (1 to 100 nm) exhibit important changes. Nanotechnology is concerned with materials and systems whose structures and components exhibit novel and significantly improved physical, chemical, and biological properties – and that enable the exploitation of novel phenomena and processes – due to their nanoscale size. The goal is first to exploit these properties by gaining control of structures and devices at atomic, molecular, and supramolecular levels; and then to learn to manufacture and use these devices efficiently. Maintaining the stability of interfaces and the integration of these "nanostructures" at micron-length and macroscopic scales are all keys to success.

Source: National Nanotechnology Initiative 2002

What is nanotechnology?

In its formal sense, the 'nano' world is where science and technology reach dimensions and tolerances in the range 100 nanometres (0.1 micrometres) to 0.1 nanometres. (...)

So nanotechnology and nanoscience are concerned with materials science and its application at, or around, the nanometre scale. A more useful definition of nanotechnology is the application of science to developing new materials and processes by manipulating molecules and atoms. It is a collective term for a set of technologies, techniques and processes rather than a specific area of science or engineering.

Source: U.K. DTI (2002)

nanotechnology *n.*
The ability to do things—measure, see, predict and make—on the scale of atoms and molecules and exploit the novel properties found at that scale. Traditionally, the nanotechnology realm is defined as being between 0.1 and 100 nanometers, a nanometer being one thousandth of a micron (micrometer), which is, in turn, one thousandth of a millimeter.

Source: CMP Cientifica 2002

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What is Nanotechnology?

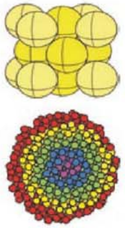
- a term that can be traced back to the 1970s but has been broadly established by research management / research policy in the 1990s
- Various definitions but none is broadly accepted
- Shared promise: understanding, manipulation and *technical exploitation* of effects that occur in matter in a dimension (1-100 nm) that was almost inaccessible so far
- Not a single technology: State of development and potential applications very heterogeneous
- STS: 'umbrella term', 'brand', 'avantgarde label‘, 'empty signifier‘, ‘general purpose technology’ - important part of societal debates about the future of technology and society
- Major part of current ‚nanotechnology' is basic science and fundamental research (N&N, 'NanoTechnoSciences')
- Current core is advanced (sophisticated) materials science & research
- Multi-/Interdisciplinary approach, (no disciplinary identity)

Nanomaterials as ‚enabling technology'

Nanomaterials	Nanointermediates	Nano-enabled Products
Nanoscale structures in unprocessed forms	Intermediate products with nanoscale features	Finished goods incorporating nanomaterials
such as • Ceramic nanoparticles • Metal nanoparticles • Carbon nanotubes • Fullerenes • Nanostructured metals • Dendrimers • Nanowires • Nanoclay	**such as** • Catalysts • Coatings • Composites • Displays • Drug delivery • Membranes • Pigments • Product additives	**such as** • Batteries • Buildings • Car tyres • Nutraceuticals • Paints • Pharmaceuticals • Sunscreens • Textiles

Source: GAO 2010, modified

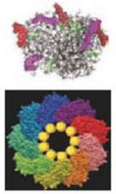
The „Four Generations“ Model



1st Passive nanostructures (1st generation products)

a. Dispersed and contact nanostructures — Ex: aerosols, colloids
b. Products incorporating nanostructures — Ex: coatings; nanoparticle reinforced composites; nanostructured metals, polymers, ceramics

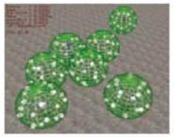
~ 2000



2nd Active nanostructures

a. Bio-active, health effects — Ex: targeted drugs, biodevices
b. Physico -chemical active adaptive structures — Ex: 3D transistors, amplifiers, actuators,

~ 2005



3rd Systems of nanosystems

Ex: guided assembling; 3D networking and new hierarchical architectures, robotics, evolutionary biosystems

~ 2010

4th Molecular nanosystems

Ex: molecular devices ‘by design’, atomic design, emerging functions

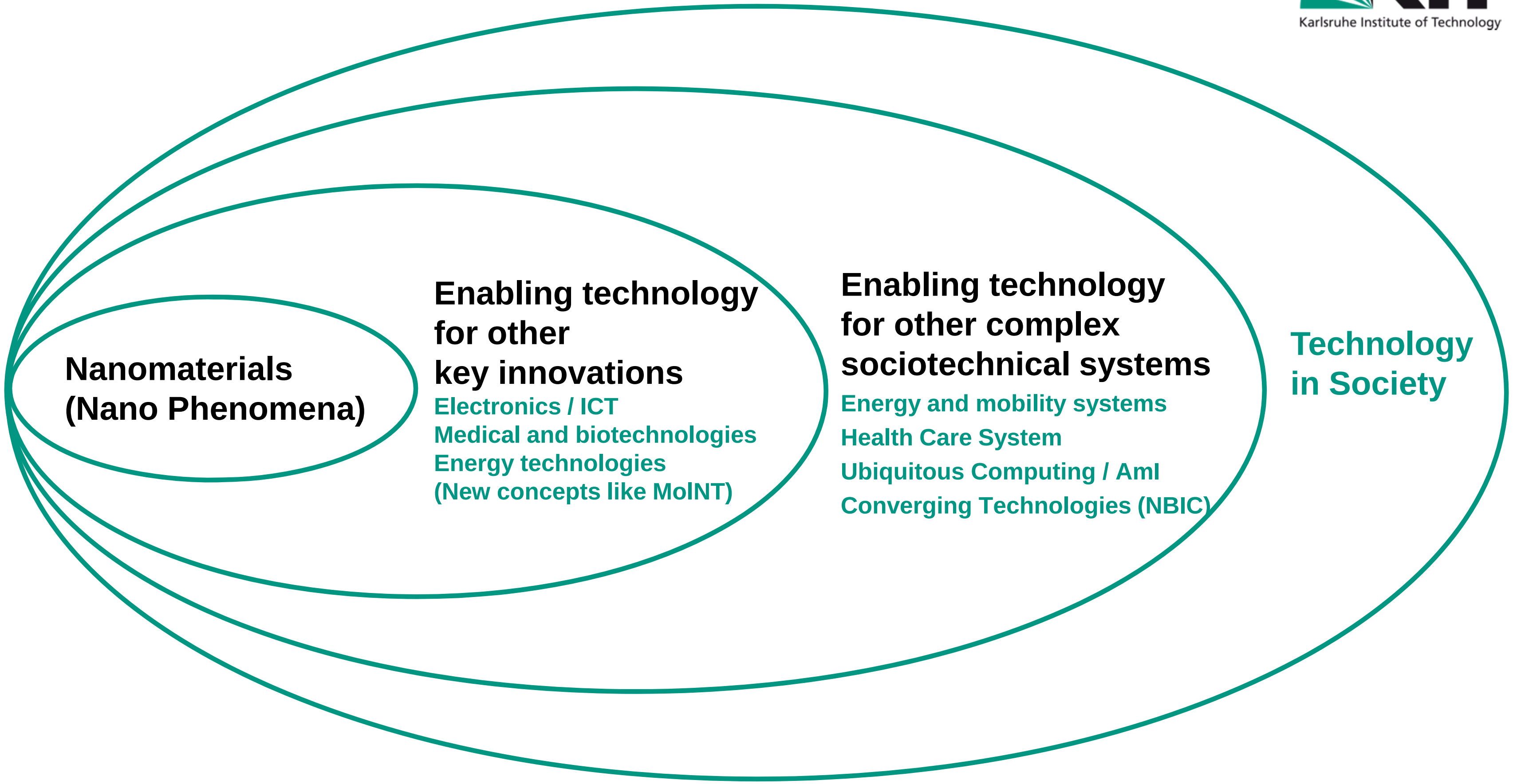
~ 2015- 2020

Frame 1

Risk Governance Frame 2

Source: IRGC 2006

Four Frames in Nanotechnology Assessment



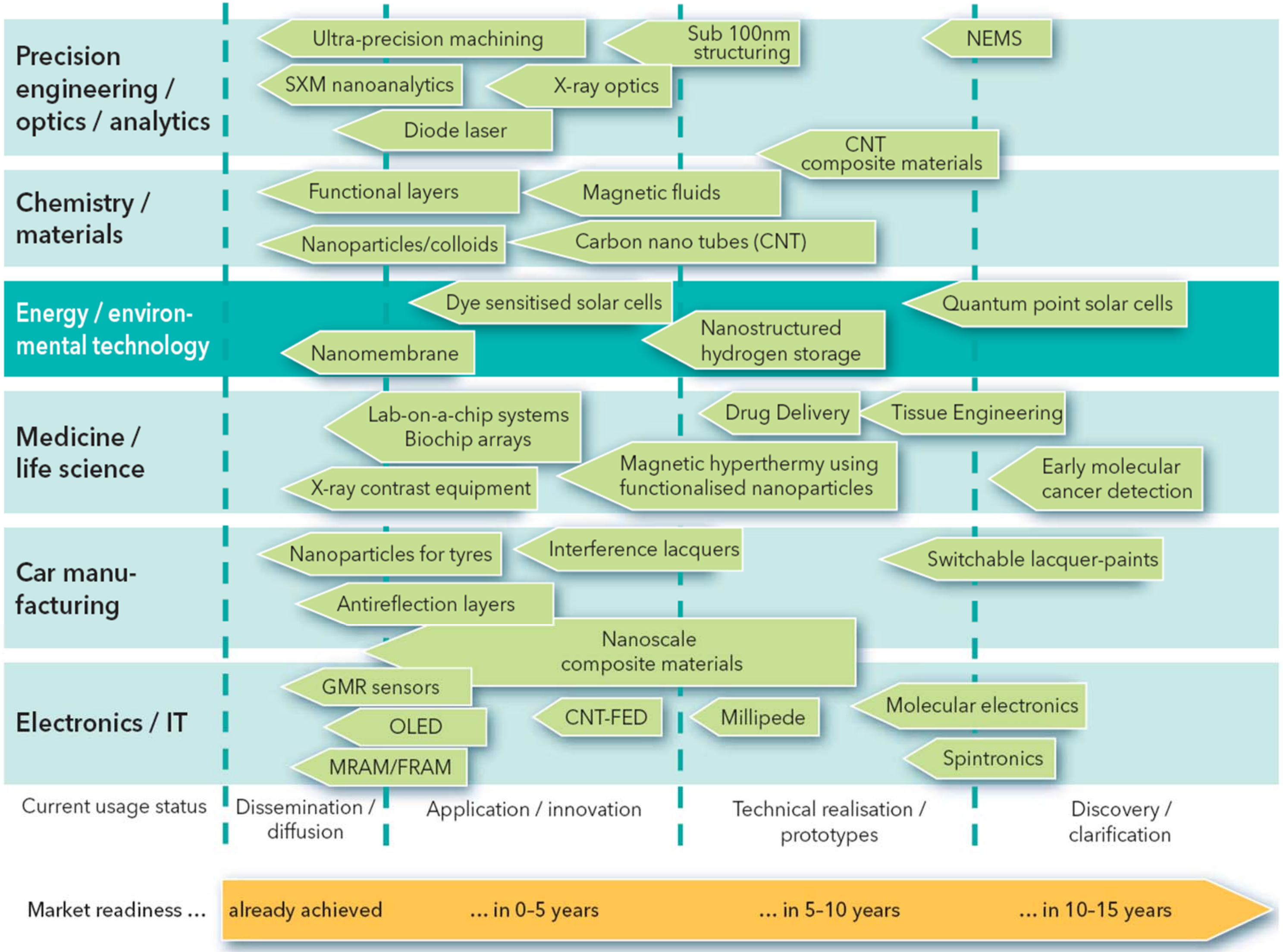
Various paths of interaction between science and society, different types of questions for S&T policy and risk governance (and TA)

→ Discussions about NT impacts cannot be meaningfully led without considering the respective frame: Different challenges, consequences, risks, …

TA adds knowledge for anticipatory governance

- TA traditionally: long-term perspectives & (unintended) implications of new technologies, systemic aspects for politics
- Growing political interest in new (additional) questions for TA:
  - Matching the needs of national enterprises with public R&D capacities
  - Improve technology transfer and commercialization of new technologies
  - Develop technologies that adress new challenges and meet societal needs (foresight)
- TA adds a broader perspective
  - Shift commercialization research from disciplinary towards an interdisciplinary perspective on innovation since commercialization is a complex process
  - An integrated view may offer deeper insights into innovation processes – understanding and avoidance of failures, more coherent policies and innovation strategies
  - Underestimation of the social dimension of innovation – Need to study ignorance, rejection or discontinuance of innovation, re-invention, anti-diffusion programs
  - Failure of innovation is discussed as a problem of the individual rather than from a systemic perspective but systemic failures are targets for political interventions
  - Call for open innovation, co-development and stakeholder engagement programs
- TA provides knowledge on many of these aspects, historical processes (analogies), roles and interplays of actors, ...

Products of NT: Strategic Foresight 2004



Source: adapted from Bachmann/Rieke 2004

Nanotechnology - Discourses

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Currently at least six (different) sustained nanotechnology discourses:

- Nanotechnology as a motor for technological innovation and economic competitiveness: ‘classic’ innovation discourse
- Consequences of new nano-enabled technologies: ICT (privacy, surveillance), medicine (biopolitics, neuroethics), ...
- Consequences of new nanotechnologies: Molecular NT, 3rd/4th Gen Nanotechnologies, Converging Technologies – visionary discourse, ‘speculative ethics’
- „Green Nanotechnology“: new innovation theme
- new, unknown material properties and its impacts on human health and the environment: ‘classic’ regulatory discourse, like chemicals policy
- NT as a further representative for ‘risk technologies’ in general debates about science in society: societal governance of science, oversight, trust in science/scientists, participation in S&T policy, (public) engagement, ...

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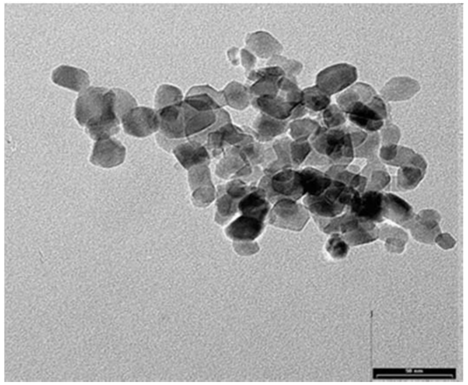
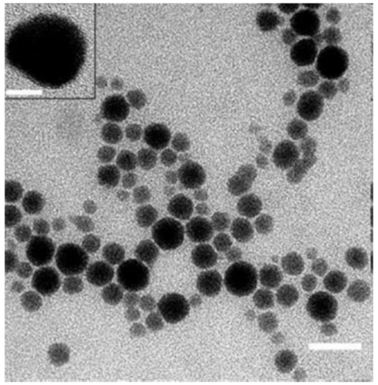
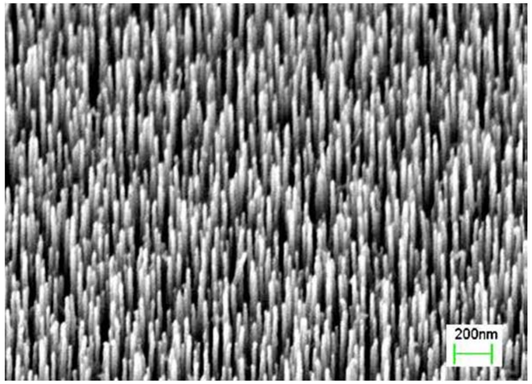
Variety of Particulate Nanomaterials



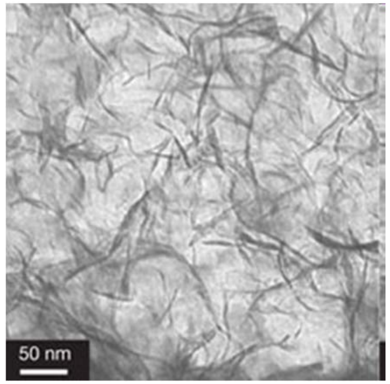
TiO_2 **Nanoparticles (P25)** (Source: UNSW Sydney)



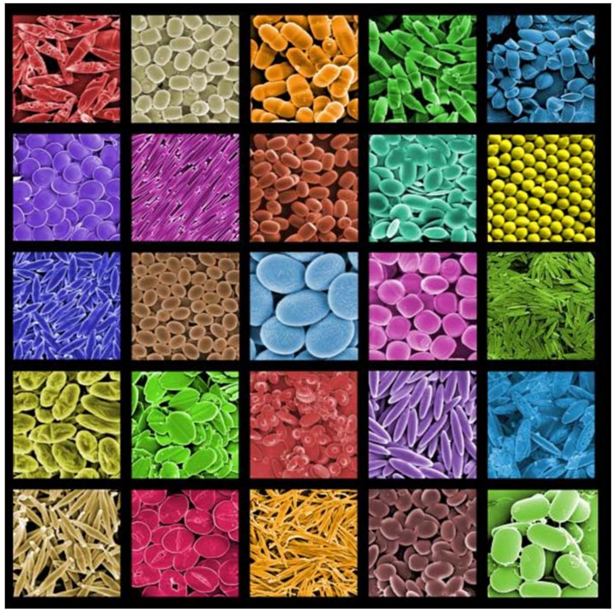
Silver Nanoparticles (Source: ACS)



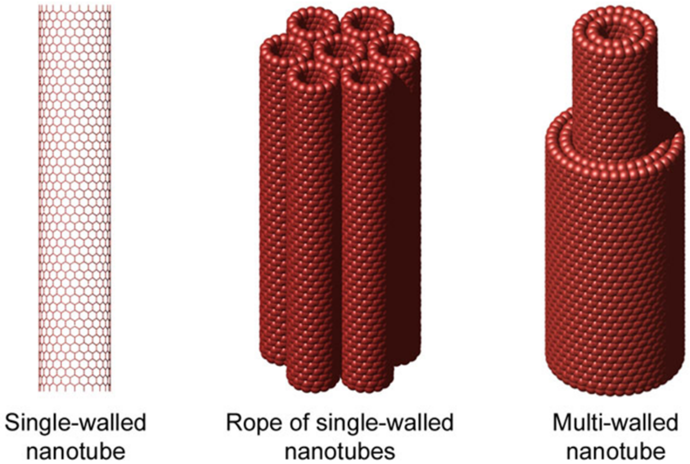
ZnO Nanorods (Source: University of Cambridge)



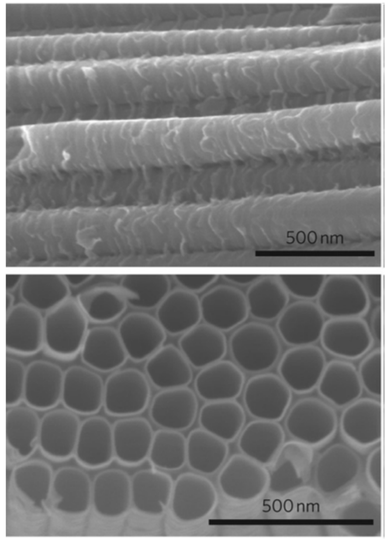
Clay Nanosheets (Source: University of Tokyo)



Polymeric Nanoparticles (Source: University of California - Santa Barbara)



Representations of Nanotubes (Source: nanotechnologies.qc.ca)



TiO_2 **Nanotubes** (Source: Yale University)

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Manufactured Particulate Nanomaterials (MPN)

- Particulate nanomaterials (PN) is an umbrella term for nanoobjects with two or three dimensions on the nanoscale (particles, fibres, rods, ...)
- PN is one type of engineered nanomaterials that is already used in a number of applications
- There are indications that some PN may pose a thread to human health and the environment
- PN can occur in nature (ash, erosion, salt, ...), can be incidentally produced (fumes, diesel, ...) or intentionally manufactured (MPN)
- Various factors may(!) affect MPN properties: size, shape, surface area, crystal structure, chemical composition, charge, aggregation properties, presence of surface coatings, particle number, methods of synthesis, and many more
- These factors may also influence human and eco-toxicity
- Some MPN are subject of public and regulatory concerns

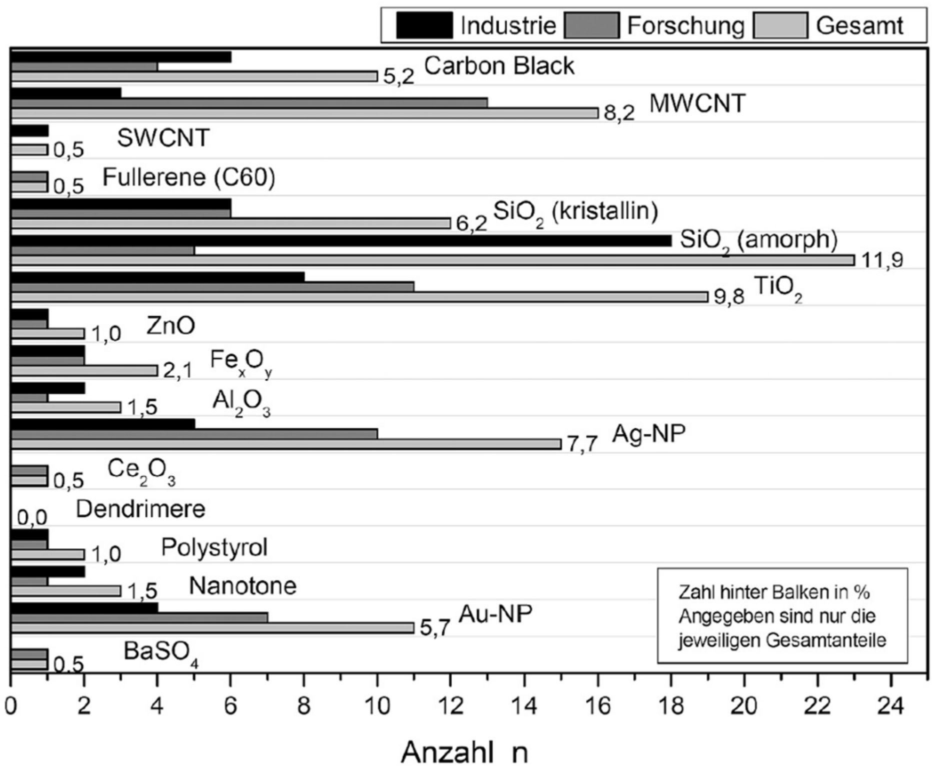
Nanomaterials on the market (2011)

Table 1 Commercialised technologies, their key characteristics and main application fields

Component or technology	*Characteristics*	*Application fields*: *Pharma*	*Cosmetic*	*Food*	*Textile*	*Automotive*	*Construction*
Aerogels (silica based)	Good thermal insulation						■
Ag (ions or nanoparticles)	Anti-microbial effect	■		■	■		
Albumin nanoparticles	Enhancement of drug delivery	■					
Amorphous carbon coatings	Enhanced gas barrier properties			■			
Carbon black	Heat resistance, durability, flexibility					■	
Carbon nanofibres	Weight reduction, scratch resistance, strength-improvement					■	
Cyclodextrins	Enhancement of stability and delivery			■			
Dendrimers (amidoamine based)	Improvement of solubility and delivery	■					
Inorganic nanoparticle composites	Increased modulus of elasticity, improved optical properties; scratch-resistance	■				■	
Nanoclay composites (magnesium aluminium silicate based)	Enhanced gas barrier properties; heat resistance, high tensile and flexural modulus			■		■	
Nanocrystals (fenofibrates)	Enhanced dissolution and absorption properties	■					
Nanoemulsions (liposomes, micelles)	Improvement of solubility; no sedimentation, flocculation, coalescence; enhanced skin penetration	■	■	■			
Polyallylamine resins	Reduction of side-effects	■					
Polyaniline nanocoatings	Conductivity, anti-static effect				■		
Polyolefin nanoparticle composites	Low shrinkage properties, improved resistance to creep					■	
Precious metal nanoparticles	Long-term catalytic activity					■	
SiO_2 nanoparticles	Hydrophobicity, oleophobicity, anti-microbial effect; high strength and durability				■		■
TiO_2 nanoparticles	UV-protection; improvement of moisture management; photocatalytic effect		■		■		■
ZnO nanoparticles	UV-protection; anti-microbial effect		■	■	■		

Source: S.P. Forster et al. Int. J. Nanotechnol., 8(2011)6/7, 592-613

Nanomaterials used by industry and research institutions in Germany



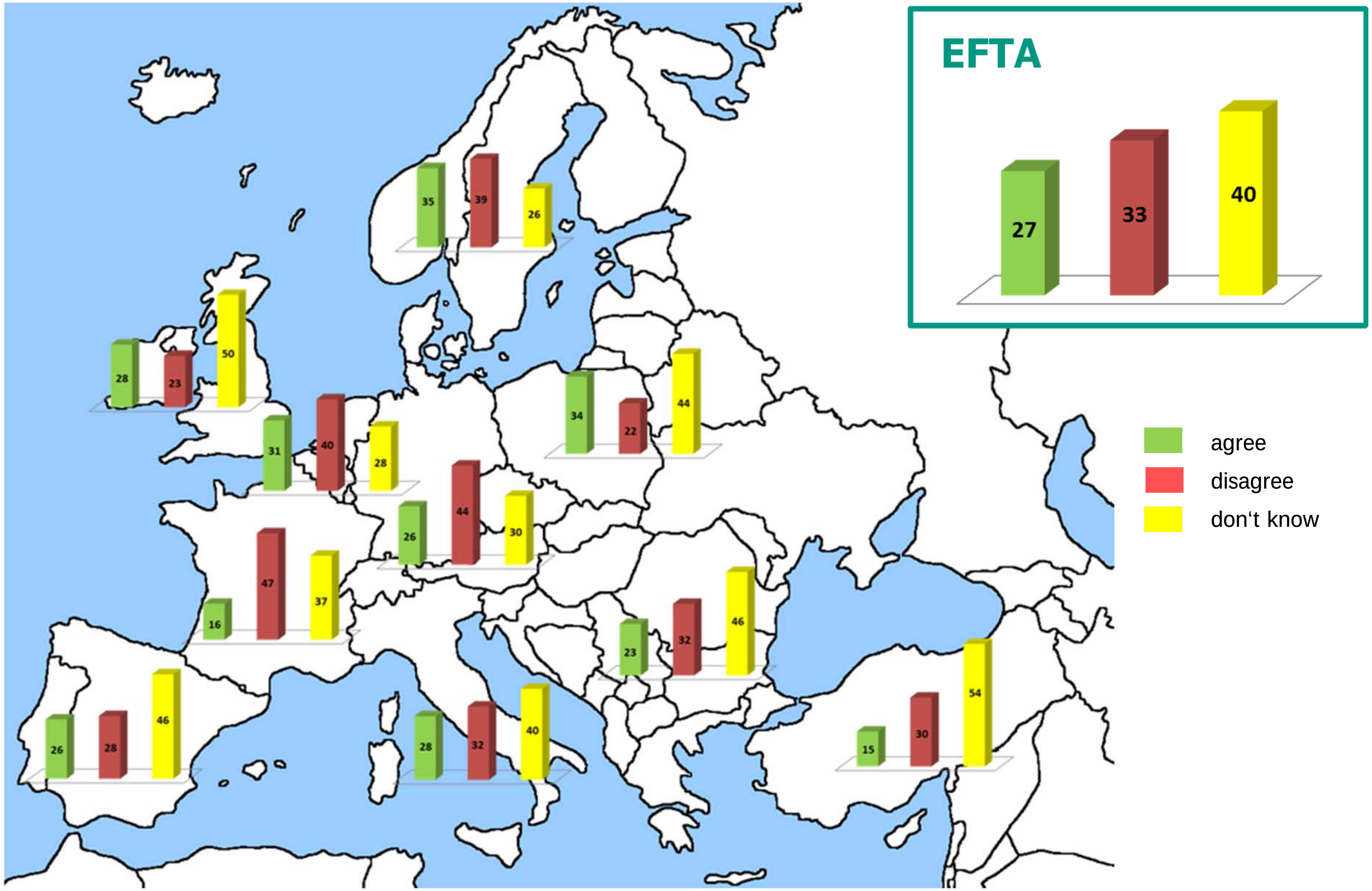
Source: Plitzko et al. Gefahrstoffe – Reinhaltung der Luft 73(2013) Heft 1/2, S. 7-13

Recent Research Situation in MPN EHS

- Large variety of MPN used or under development, only few studied
- High research dynamics: Increased funding of toxicological studies, efforts to review and integrate distributed research results (meta studies), but in many cases results still inconclusive
- Hazard data can be reproduced only partially, transferability under debate
- Most studies via inhalation route, poor data on skin and gut absorption
- Substantial lack of measured and modeled exposure data of MPN, for humans and for the environment
- Results of ‚no effects‘-experiments are usually not published
- Published interpretations of experimental results, especially those regarding potential impacts on human health and on the environment, are still insufficient, contradictory and controversial.
- Regulators, citizens, society at large expect answers
- EHS Risks of MPN is one of the important NT discourses and appears to influence public attitudes towards NT in general.

Nanotechnology and Health

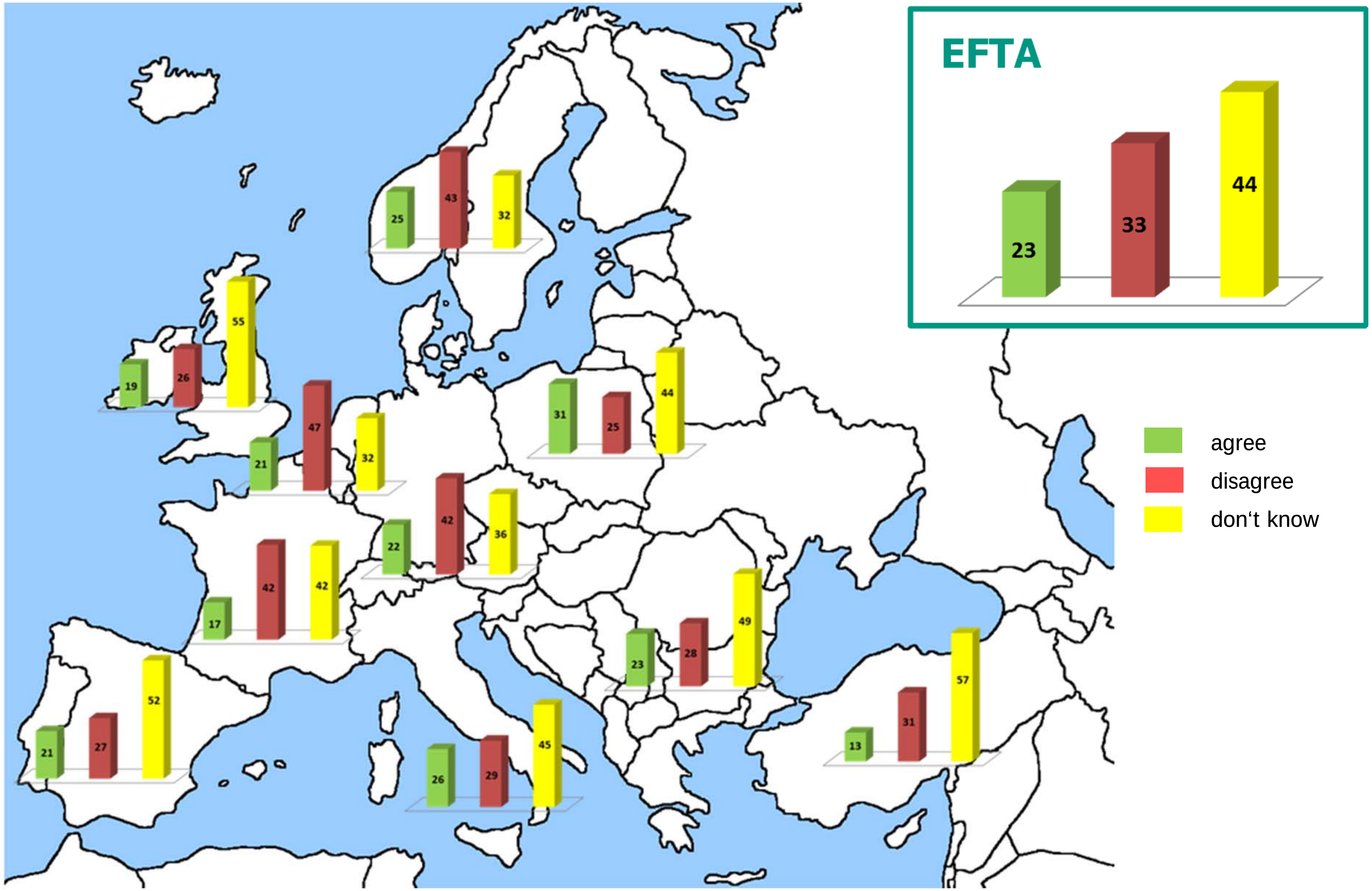
St: Nanotechnology is safe for your and your family‘s health.



Data Source: Special Eurobarometer 341 / Wave 73.1: Biotechnology. Fieldwork Jan/Feb 2010

Nanotechnology and Environment

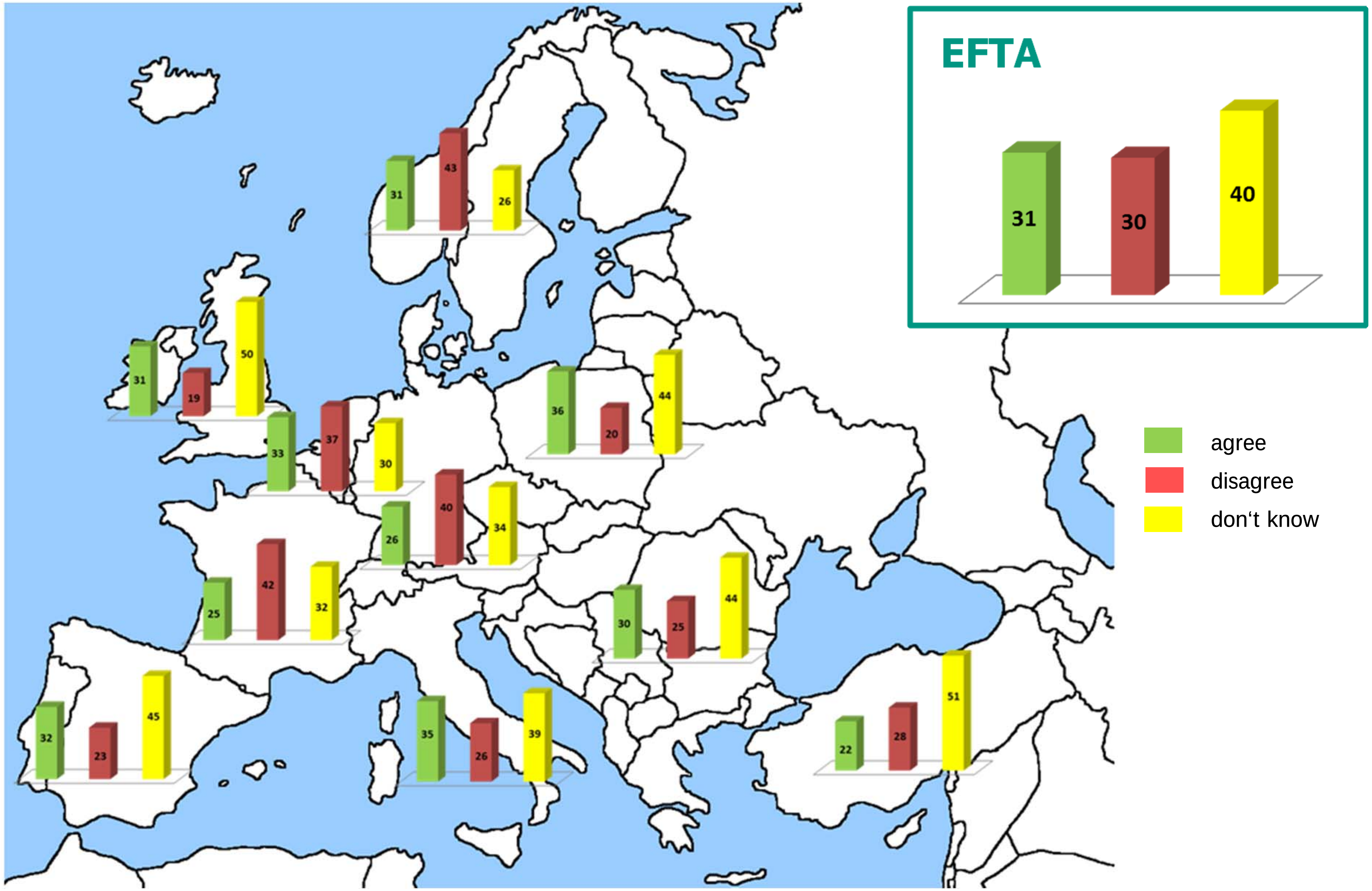
St: Nanotechnology does no harm to the environment.



Data Source: Special Eurobarometer 341 / Wave 73.1: Biotechnology. Fieldwork Jan/Feb 2010

Nanotechnology and the Future

St: Nanotechnology is safe for future generations.

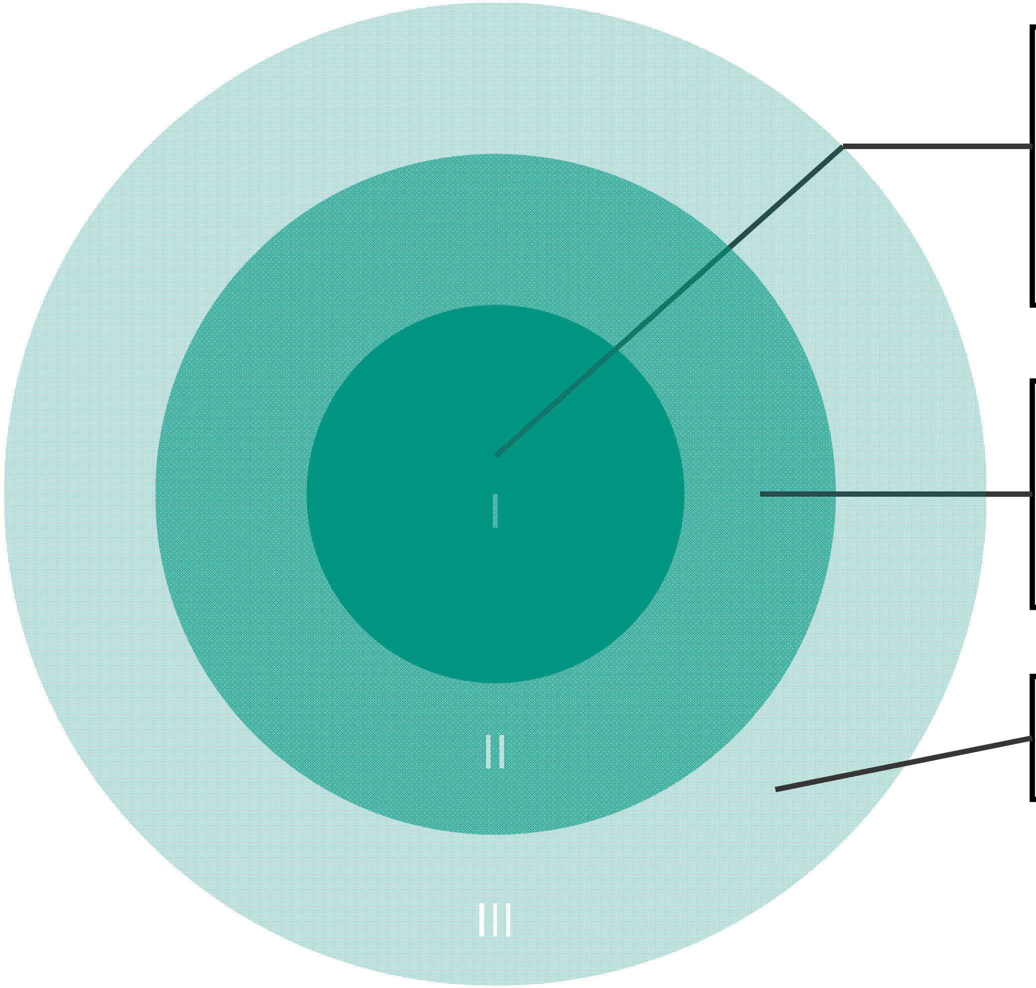


Data Source: Special Eurobarometer 341 / Wave 73.1: Biotechnology. Fieldwork Jan/Feb 2010

Citizens' Focus Groups – Recurring Themes

- Balanced perspective: Positive attitude in general - scepticism in detail
- Chances: medicine, energy, environment, relief from household routines
- Risks / poor acceptance: food, untested products on the market, 'thoughtless commercialization', (military applications)
- MPN are rarely distinguished from nanotechnology
- Oversight: vigilant and acting government, research (and marketing) under governmental supervision, 'under control'
- Wish for more transparency of governmental and industrial activities
- felt able to deal with scientific uncertainties when adequately informed
- Overall, didn't feel well informed – Wish for improvement
- Positioning oriented on a consumer perspective
- Product information, mandatory labelling, 'nano seal', independent product tests, 'declaration of harmlessness' by government
- Binding force of regulatory instruments – doubts in voluntary measures

Three views on regulation



Regulation as a specific form of governance: a set of binding norms and rules, defined in codified law, usually executed and enforced by governmental institutions

Regulaton as totality of governmental steering and programs, independent of the modes, forms and instruments of governance

Regulation as any form of societal control by social norms and institutions

nach Jordana/Levi-Faur 2004 und Wegrich 2009

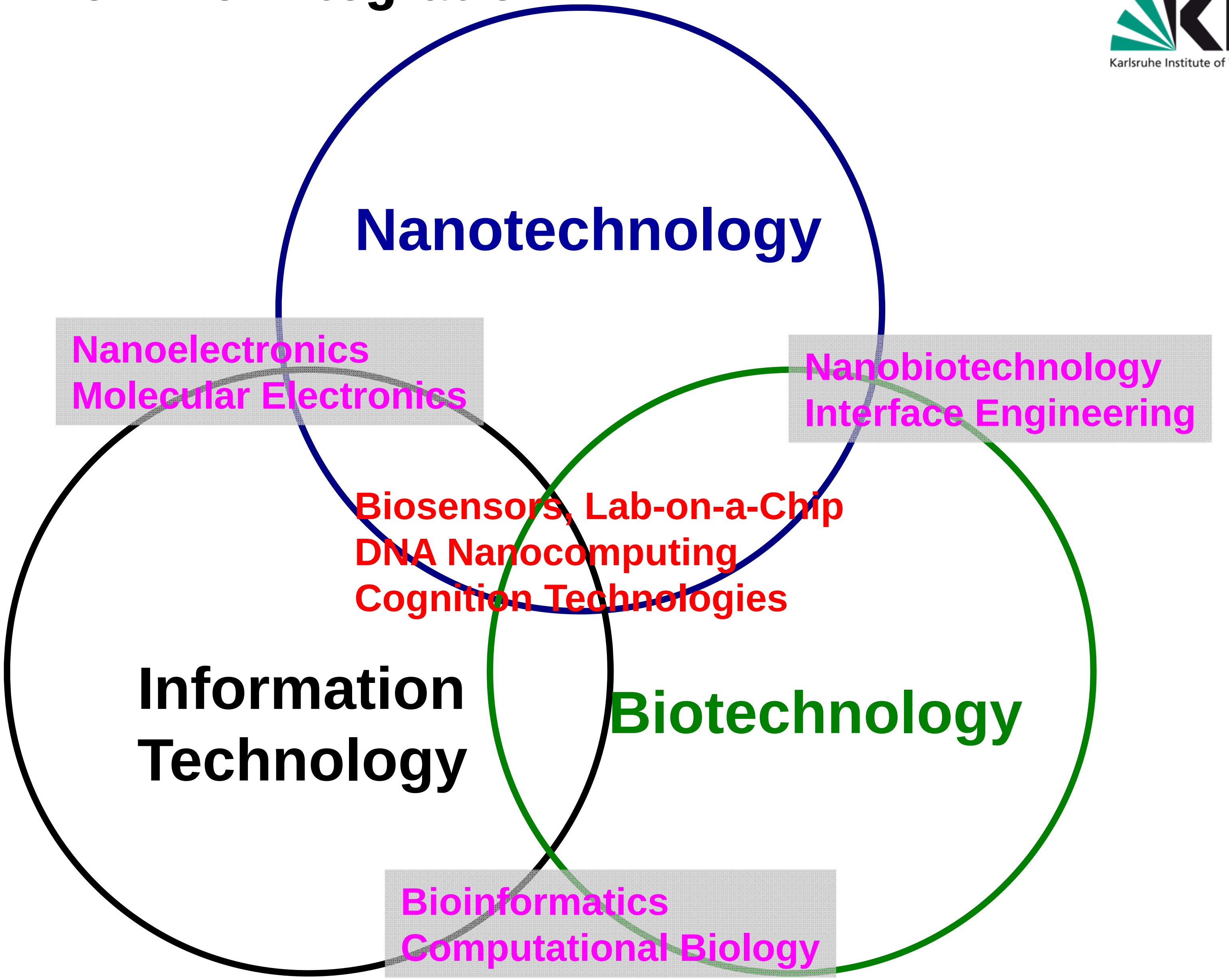
Risk Management of MNP: Regulatory Debates

- Definition of nanomaterials / nanoparticles
  - Regulatory role of harmonized definition
  - Elements of a definition: Size range covered, functionalities, ...
- Nanomaterials in REACh (European Regulation of Chemicals)
  - “Old” or “new” substance
  - Separate dossiers for nanomaterials
  - Reduced quantitative thresholds for registration / evaluation
- Regulatory instruments
  - (Mandatory) Labelling (of consumer products)
  - (Public) Register for nanoproducts (or nanomaterials)
  - Rules and recommendations for occupational health riisk reduction
  - Action plans, funding, consultations, tools for preliminary risk assessment
- Role and Operationalization of the Precautionary Principle
- Nanomaterials in sectoral law

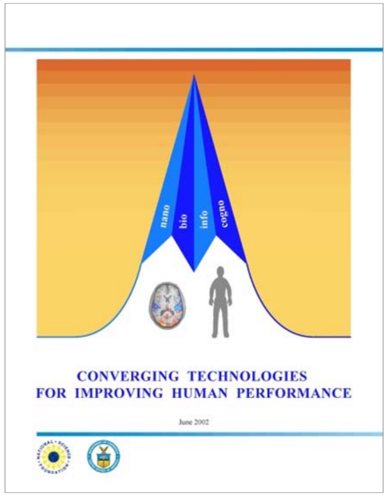
Two Different Regulatory Paradigms (stylized)

	Reactive	Precautionary
Major players	Most industries, „innovation“ ministries, (research administration)	CSO, some TPEA, „protection“ ministries
	Intervention justified when scientific evidence of hazard / harm	Intervention already justified when reasonable abstract concern
Current regulatory framework for NM/NT	Mainly sufficient, only minor adaptions necessary	Insufficient for nano specific challenges, substantial changes needed
Definition of NM	Size between 1 – 100 nm, higher upper limit when harm, additional consideration of PSD and VSSA	Size + certain properties as heuristics, upper limit 300 nm, reduction possible in specific regulatory contexts
REACh	Sufficient after minor adaption, nanoforms part of substance dossier	NM as new substances, own dossiers, reduced quantity thresholds, additional information requirements
Labelling	In l.o.i., where required, o.k., no general nano label, may be perceived as warning and confuse customers	Mandatory labelling for all products releasing MPN or use them to enable specific properties
Product register	Use of existing registers for products or substances, no general public register	Semi public register and notification requirements for nano products, some content available to consumers

Nano-Bio-Info Integration



Converging Technologies (1)



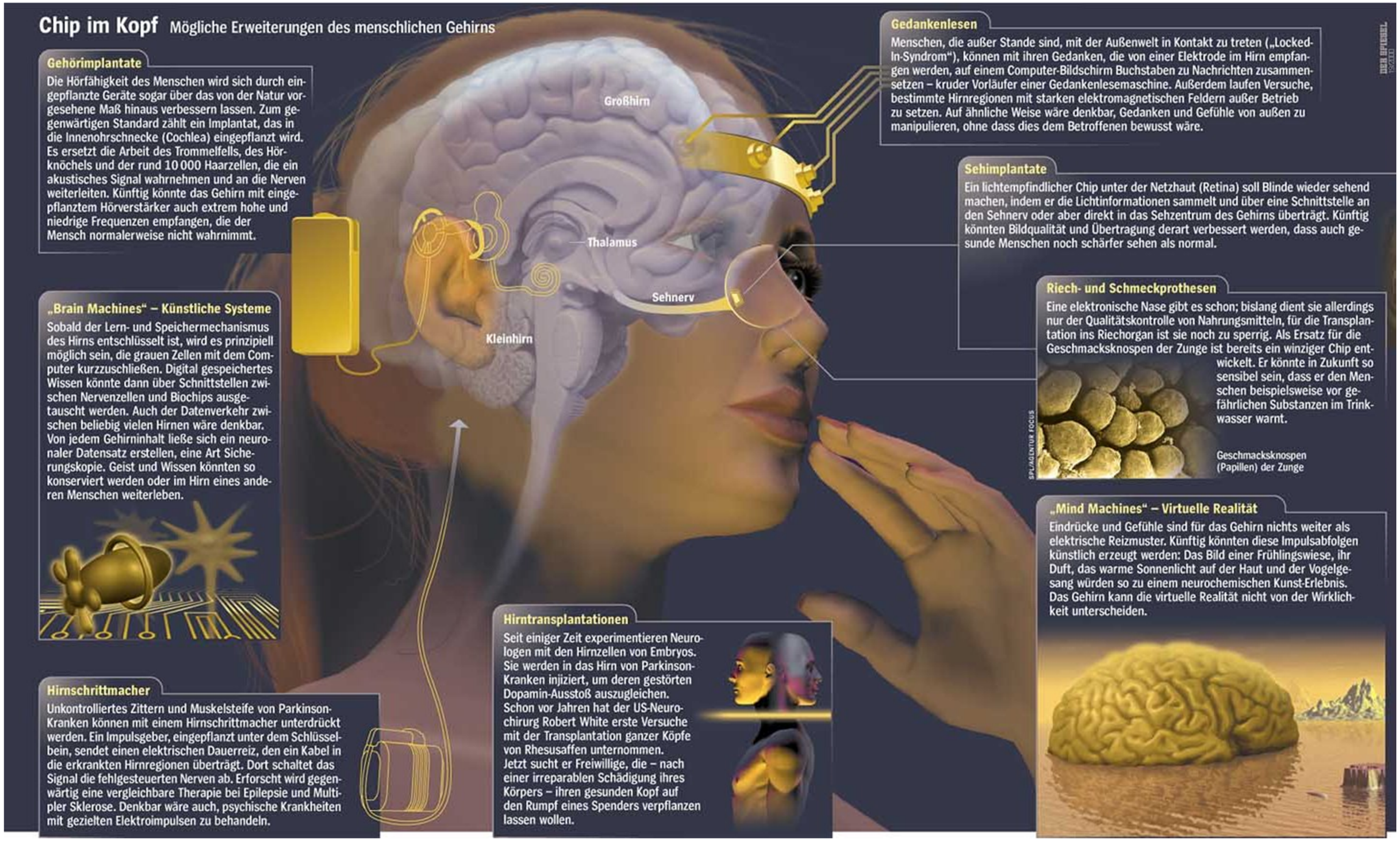
- NSF/DOC-sponsored Workshop Report 2002: „Converging Technologies for Improving Human Performance“
- The phrase “convergent technologies“ refers to the synergistic combination of four major “NBIC“ (Nano-Bio-Info-Cogno) provinces of science and technology, each of which is currently progressing at a rapid rate.
- Convergence of diverse technologies is based on material unity at the nanoscale and technology integration from that scale. (...) At this unique moment in the history of technical achievement, improvement of human performance through integration of technologies becomes possible.

CT / NBIC Ideas (taken from various studies)

- Artificial molecular muscles [NB]
- Biosensors implanted under the skin or ingested for diagnosis, therapeutics, prognosis and monitoring of treatment [NBI]
- Biotechnology and nanotechnology in relation to spread of viruses [NBI]
- Brain-machine interaction and neuromorphic engineering [NBIC]
- Brain stimulation [NBC]I?
- Gene therapy [NB]
- Image data banks and pattern recognition [NBI]
- Improving sensorial capacities and expanding sensorial functions [NBIC]
- Intelligent artificial noses (diagnosis of disease, fast detection of microbes) [NBI]
- Intelligent drug delivery [NBI]
- Memory improvement and restitution, metabolic enhancement [NBC]I?
- Nanopumps [NB]
- Prosthetic vision / hearing [NBC]I?
- Rationally designed drugs and targeted intelligent drug delivery [NBI]
- Regenerative medicine [NBIC]
- Reproductive technologies [NB]
- Routine pre and post natal screening and diagnosis of all single gene disorders [NBI]
- Synthetic bio-compatible materials [NB]
- Telemedicine: monitoring, diagnosis and treatment [NBIC]

Source: HLEG *Foresighting the New Technology Wave* Special Interest Group 1, modified, NBIC Workshop Report

Ideas 2: Possible Extensions of the Human Brain



Quelle: **Der Spiegel 19/2000**

Blurring the boundaries between man and machine

- Fundamental processes of life happen on the nanoscale, essential constitutents have this dimension
- Nanotech and IT enable study, imitation(?), understanding (?), control(?) and manipulation(?) of biological processes and systems (incl. human body – brain – mind – soul?)
- Linked to numerous fundamental philosophical, moral, theological questions
- If proven to be feasible, opens technological options with far-reaching implications:
  - Pharmaceutics (chemical-biological) complemented or replaced by ‚engineering'?
  - Interlinkage between complex biological and technical processes and systems seems to be possible
  - Technical representation of human cognition, emotion, intelligence possible?
  - Human body: From therapy to improvement, reshaping, enhancement, augmentation, ...

Questions for TA (ELSI) between old ...

old: Revision of many arguments from other technology debates (AI, 'Cyborg', Bioethics, ...)

- Limits of ‚technization' of man? Role of the therapeutic imperative. Possibilities and limits of self-design
- Research for the improvement of the ‚deficient creature' (Mängelwesen) man as a goal of public research?
- The human body as a machine in need of maintenance and repair? Implications for human identity?
- Social norms. Dealing with deviations. Social pressure.
- Boundaries between humans and non-humans? Human rights for cyborgs? Problems of hierarchies?
- Autonomy and subjectivity called into question?
- Principle of reversibility prohibits application
- Safety in everyday use. Responsibility for malfunction or illegal behaviour. Liability.
- Damage prevention / Avoidance of misuse?

… and new

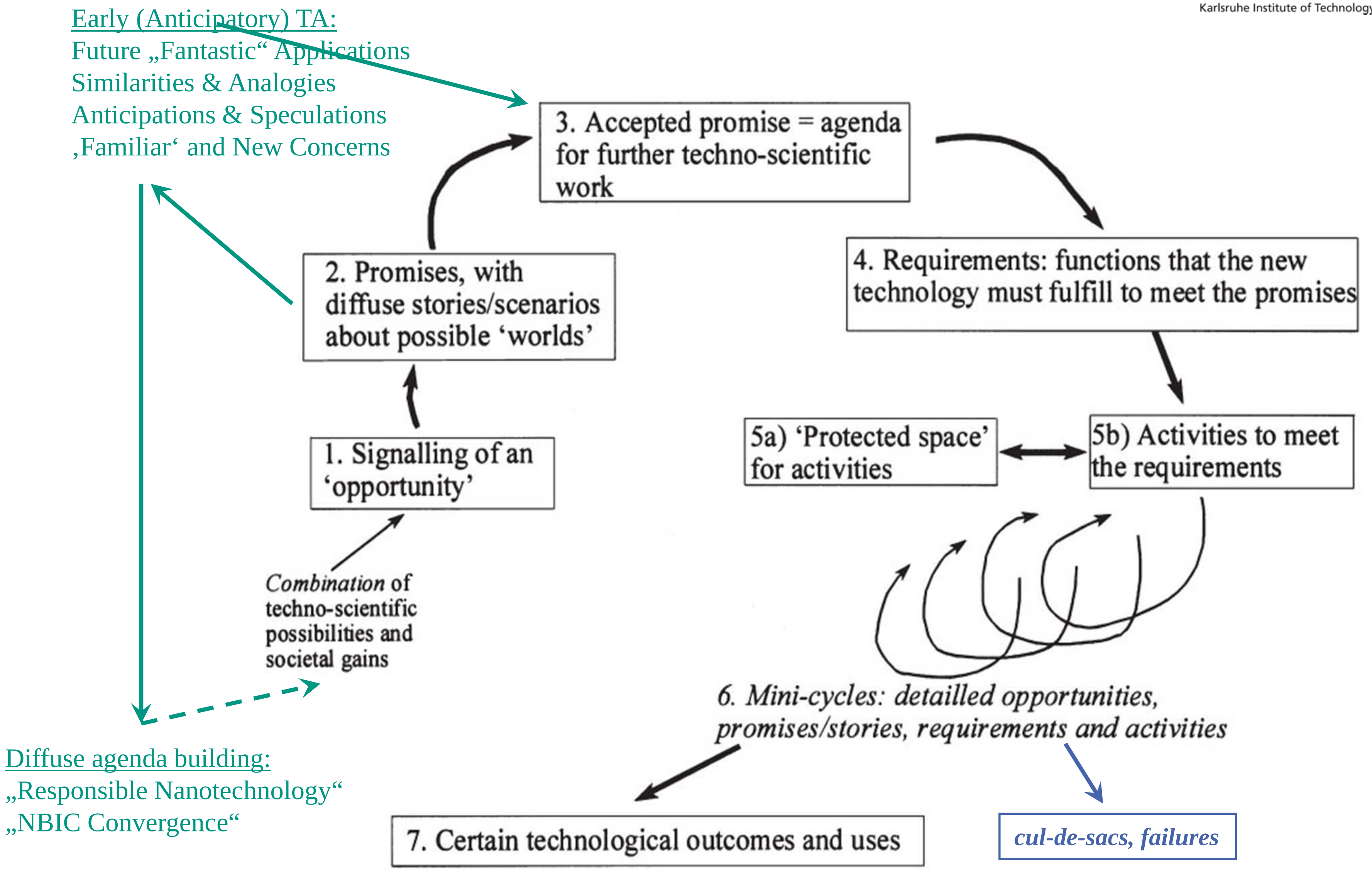
New: Changing technological opportunities and social reality

- Speed of technological development restricts opportunities for experience-based societal reflection (?)
- Individualization and social competition: Cosmetic surgery socially accepted, (Pharmaceutical) enhancement: Stimulants, anabolics, psychopharmaceuticals …
- Ongoing economization of health care system and medical ‚service providers'
- Changing balance between security and privacy, new definition of 'national security' after 9/11
- Unreflected application of innovations in medical technology
- Boundary between 'Restoring' und 'Improving'?
- Problems of distribution and allocation within the healthcare system („NBIC-divide“)?

TA Impact: Phase 1 (ca. 2000-2005)

- Central part of the current practice of TA in Germany: research with the aim to provide knowledge about (unintended) implications of S&T for orientation and action of political decision makers.
- Especially in the case of nanotechnologies, TA institutions started broad ELSA or ELSI projects early that integrated TA researchers and academics from various disciplines.
- Projects resulted in comprehensive reports that structured the field, assessed (enactors') visions, created knowledge about (potential) impacts and discussed political options (incl. 'urgency').
- Projects served as 'test beds' ('labs') that allowed for 'experimentation with ideas', enabled anticipation and feedback for both enactors and selectors and served as early arenas for negotiations.
- Projects support both camps: help developers to be prepared for future selection pressures and STP enactors to design and coordinate future governance (funding priorities, regulatory expectations, ...)

Promise-Requirement Cycles

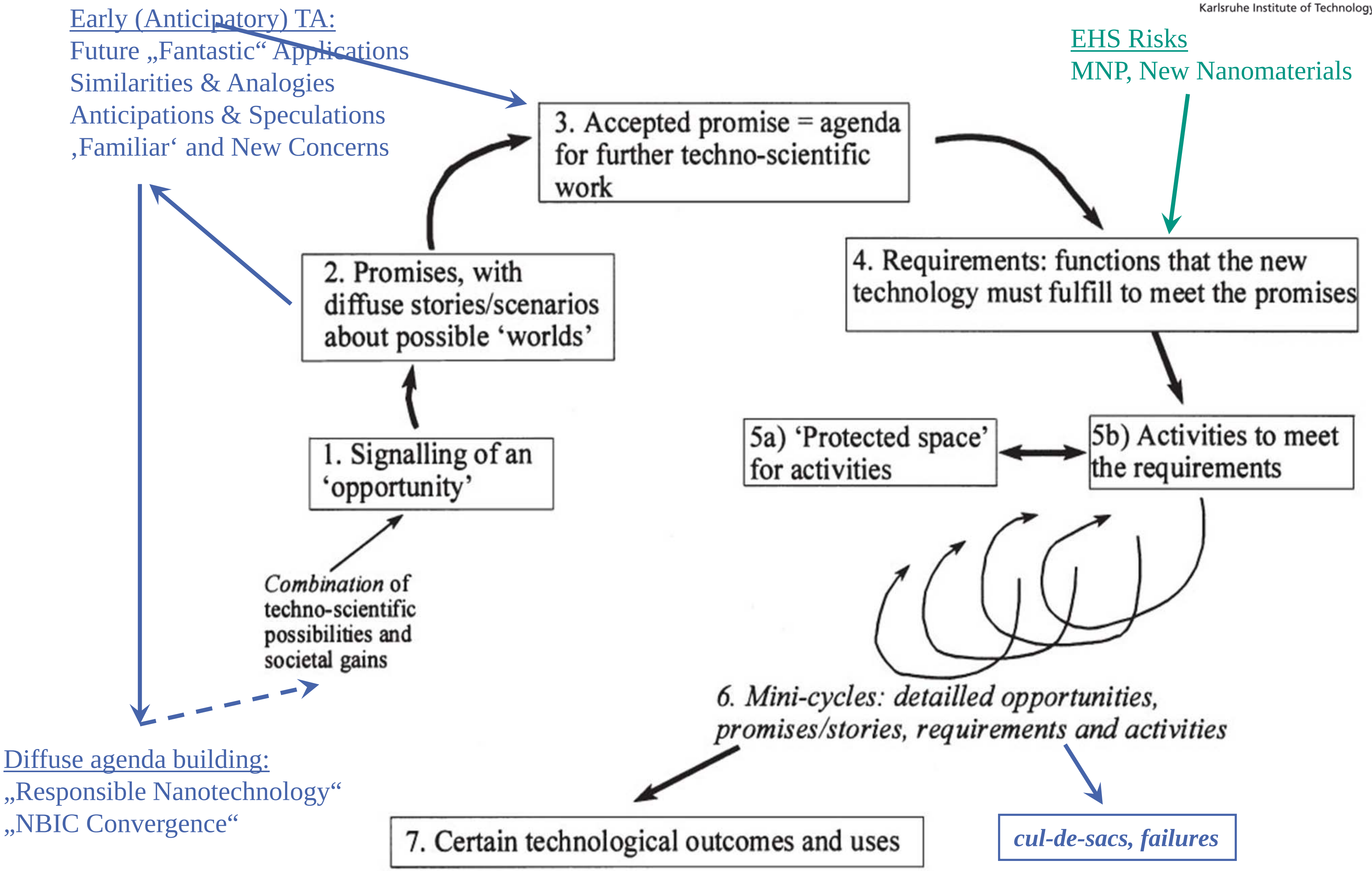


Geels/Smits 2000 cit. van Lente/Rip 1998

TA Impact: Phase 1

- The results of these projects
  - were referred to in numerous publications of scientific commissions advising policymakers (agenda building),
  - 'pre-selected' (technological and regulatory) options and challenges,
  - created awareness among CSOs and initiated and/or directly contributed to various forms of public deliberations (citizens' dialogues, consensus conferences, parliamentary debates) (opening up societal debates),
  - legitimized TA researchers as individual experts in the work of advisory bodies and in the design and analysis of deliberative exercises,
  - structured a fuzzy and complex topic and connected (parts of) it to typical disciplinary research (normalization),
  - initiated further problem-oriented research within TA/ELSA(I) communities.
- In doing so, TA contributed to the shaping of the sociotechnical framework of emerging technologies, to the development of accepted promises and thus also to the shaping of the technologies themselves.

Promise-Requirement Cycles



Geels/Smits 2000 cit. van Lente/Rip 1998

Challenges of MPN EH risk assessments

- Only very few studies dealing with MPN risk perceptions of scientists, empirical studies need further validation and refinement
- For many MPN EHS risks only poor knowledge base
- Selection of endpoints ‘analogy driven’ (mainly based on experience from ultrafine airborne particles research)
- Significant body of publicly funded research is science driven rather than problem oriented (A place for regulatory toxicology?)
- Even on a shared knowledge base, hazard and risk assessments of individual scientists are varying widely (ambiguity)
- Plurality of positions for a number of reasons:
  - Tacit knowledge plays a role in risk judgements: experimental experience, methodological and technical problems, knowledge about research groups, ...
  - Risk frames depend on position in technology development phases (Powell 2007)
  - Disciplinary and individual standards, quality measures and assessment bases
  - Shared values but discrepancies in risk interpretations (interpretative ambiguity) or differences in value systems (normative ambiguity) among scientists

Phase 2: Focus on MPN concern assessment

- TA institutions involved in research projects on MPN EHS and regulatory strategies
- Propose strengthening concern assessment in risk governance strategies and develop broader risk management strategies:
  - Intensify work on ‘orphan’ hazards (routes, endpoints, ...)
  - Consider to make the publication of nanotoxicological “no effect”-data data mandatory (especially when gained within publicly funded projects)
  - Support development of measurement techniques that allow for regulatory enforcement
  - Policymakers and stakeholders articulate different requirements re definitions which are (partially) shaped by respective interests and regulatory goals – work towards a harmonized regulatory/legal definition for MNP / nanomaterials
  - Work towards an mutually agreed regulatory paradigm for nanomaterials
  - Develop options for public information on MNP risks and product labelling
  - Support the development of a suitable risk characterization heuristic for MPN
  - Investigate the need for a new regulatory framework for nanomaterials
- Attempts to broaden and (re-)contextualize toxicological research – another type of ‘midstream modulation’?

To sum up (1)

- Technology Assessment as a practice can be understood as an instrument or tool of „soft“ regulation
- TA informs and supports policymaking and society at large in setting agendas and priorities in S&T policy and anticipatory governance
- Technology assessment, beyond this, has a communicative dimension by which it becomes part of wider societal debates on possible futures
- To systematically deal with the (unintended) consequences of technological change in a well-structured way is an important element of political, and partially also public, expectations on innovation governance
- Political programs and institutions demand (and fund) TA on nano and use or implement (parts of) its results
- Parliamentary debates on nano regularly refer to TA
- By doing all that, TA creates responsiveness and contributes to societal control and the formation of social norms with regard to nano

To sum up (2)

- TA researchers early joined various processes of positioning and mutual learning amongst innovation actors and stakeholders, especially about how to assess the impacts and govern the dynamics of nanotechnologies.
- By doing that, they acquired an unfamiliar role. By contributing knowledge to decision making (and shaping it) in various arenas, TA researchers are no longer only observers, they become actors.
- In Phase 1, TA served as a test bed (“lab”) where enactors and selectors experimented with ideas. The outcomes, i.a., structured S&T programmes and shaped media and stakeholder discourses. (“testing through studies”)
- In phase 2, TA contributed to opening up risk discourses (concern assessment) by surveying stakeholder and public perspectives (“creating agenda-building knowledge”).
- TA researchers not only observe, generate and become ‘enrolled’ (Bensaude-Vincent). They also investigate their own ‘laboratories’ and its role as actors in science & technology policy as participant observers.

Thank you very much for your attention

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