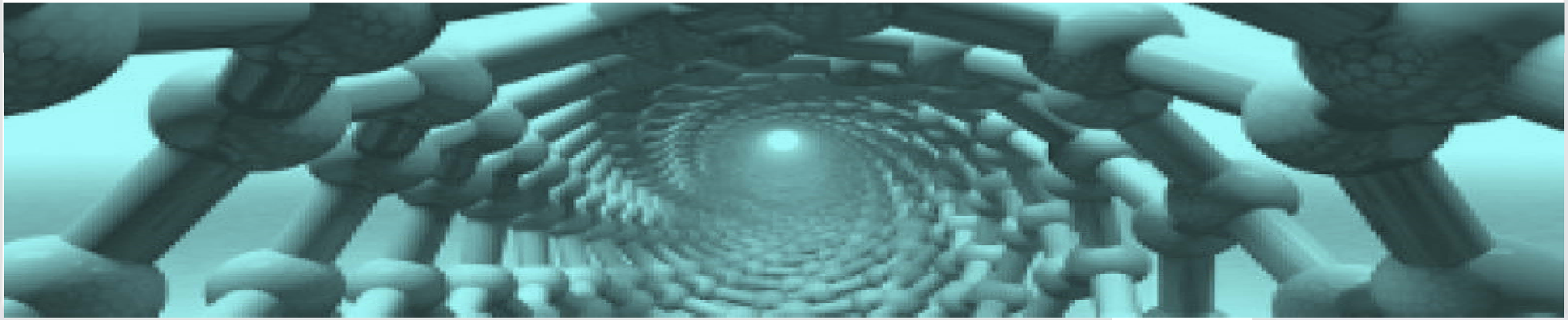
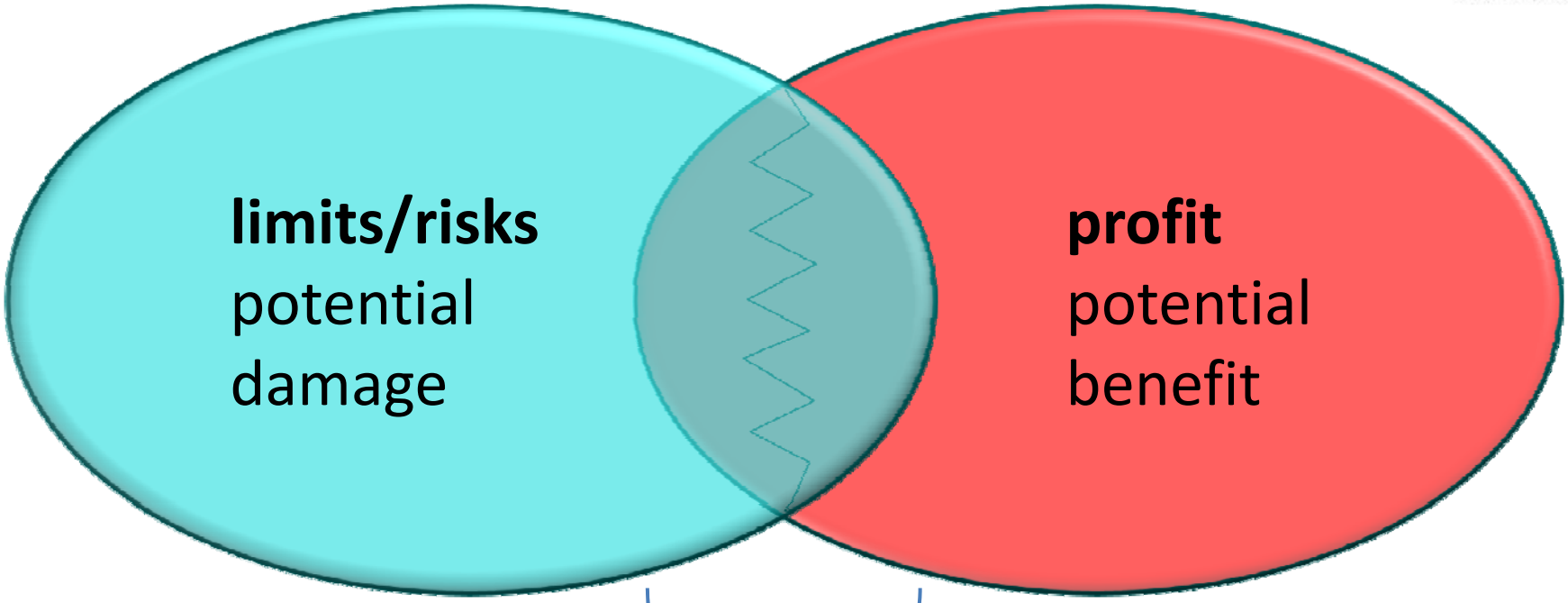
Constructive TA in early phases of technology development - A promising route for a more responsible development of nano technologies?

Marcel Weil[1,2]

[1]Institute for Technology Assessment and System Analysis
[2] Helmoltz-Institute Ulm for electrochemical energy storage (HIU)





“Environmentalists”
More worried, than happy
innovations should only
introduced of no
damage can be foreseen

responsible technology development
potential advantages but also possible restrictions and risks are considered (CTA/SA)

“Technology enthusiast”
Don’t worry, be happy
innovations should be
pushed forward, possible
damages will be
managed

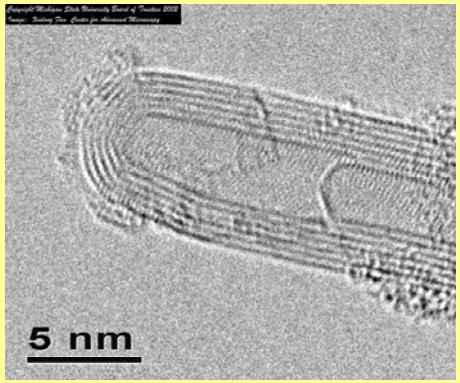
Constructive TA

- Originated in the mid-1980s (Arie Rip)
- Technology development is considered as a complex process, which use structures of a strategic game (Hack 1995)
- Broaden the design of new technologies (and the redesign of old technologies)
- Inclusion of more aspects and more stakeholders
- Feedback of TA/SA activities into the design phase of technologies

Nano-Technology

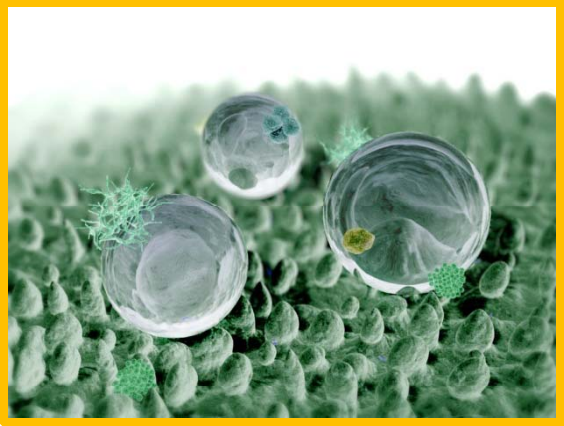
Nano Objects

- ❖Nanoparticle
- ❖Nanofibre
- ❖Nanoplate
- ❖“Nanomaterial”



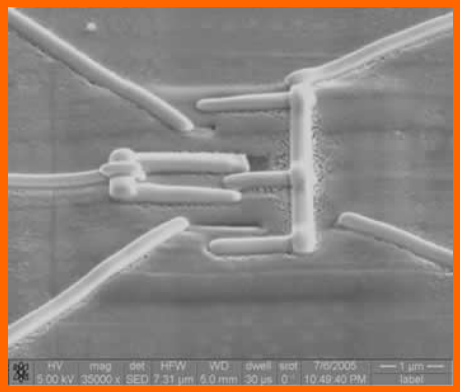
Nano Surface

- ❖Nano structured surface Imprint
- ❖Nano structures

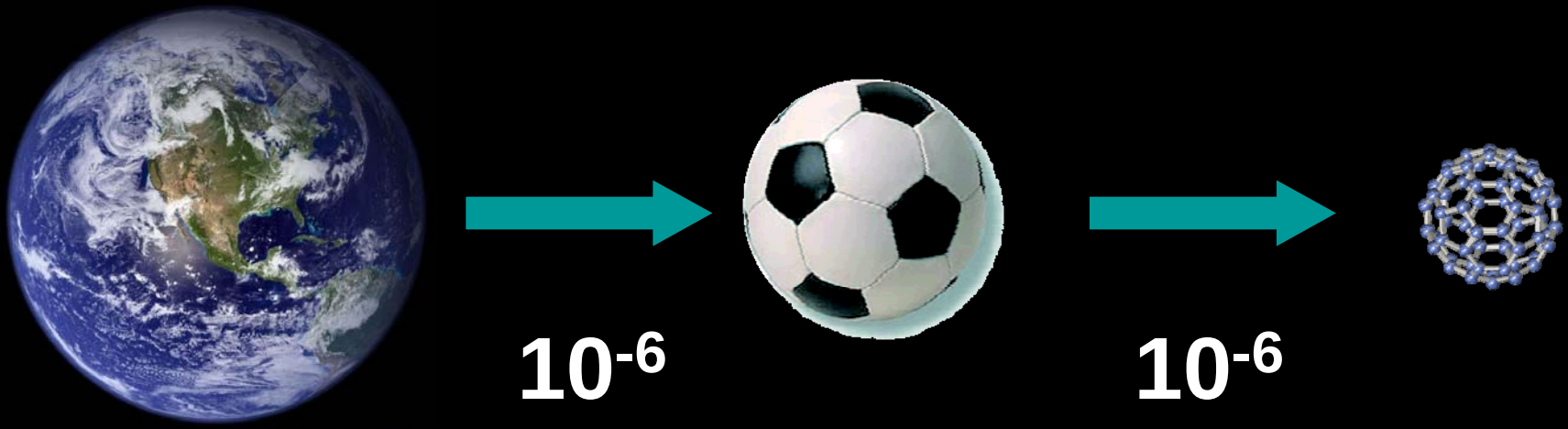


Nano Engineering

- ❖Nanodevise
- ❖Nanofabrication



Size Relation 10^{-9}



Potential risk for human health and enviroment

Nano objetcs potential danger to human health and environment

Charakteristika	Wichtung	SWNT	MWNT	Nano-Clay	CdS	ZnO	TiO_2	Dendrimere	Fullerene	Nano-Pharma
Hinweis auf toxische Wirkung	35%	●	●	○	●	◎	○	◎	●	○
Nano reaktiver als Bulk	15%	●	◎	○	◎	◎	◎	◎	●	○
Bulkmaterial ist toxisch	5%	○	○	○	●	○	○	○	○	○
Nicht biodegradierbar	10%	●	●	○	●	●	●	●	◎	○
Geringe Tendenz zur Agglomeration	5%	○	○	○	○	○	○	◎	○	○
Einfache Reinigbarkeit/ Charakterisierung	10%	●	●	◎	◎	◎	◎	○	○	◎
Hinweis auf Mobilität/ neg. Wirkung im Körper	10%	●	◎	○	●	◎	○	●	●	○
Hinweis auf Mobilität/ neg. Wirkung in Umwelt	10%	◎	◎	○	◎	◎	○	●	●	○
Potential danger		■	■	■	■	■	■	■	■	■

■ **High**
■ **Middel**
■ **Low**

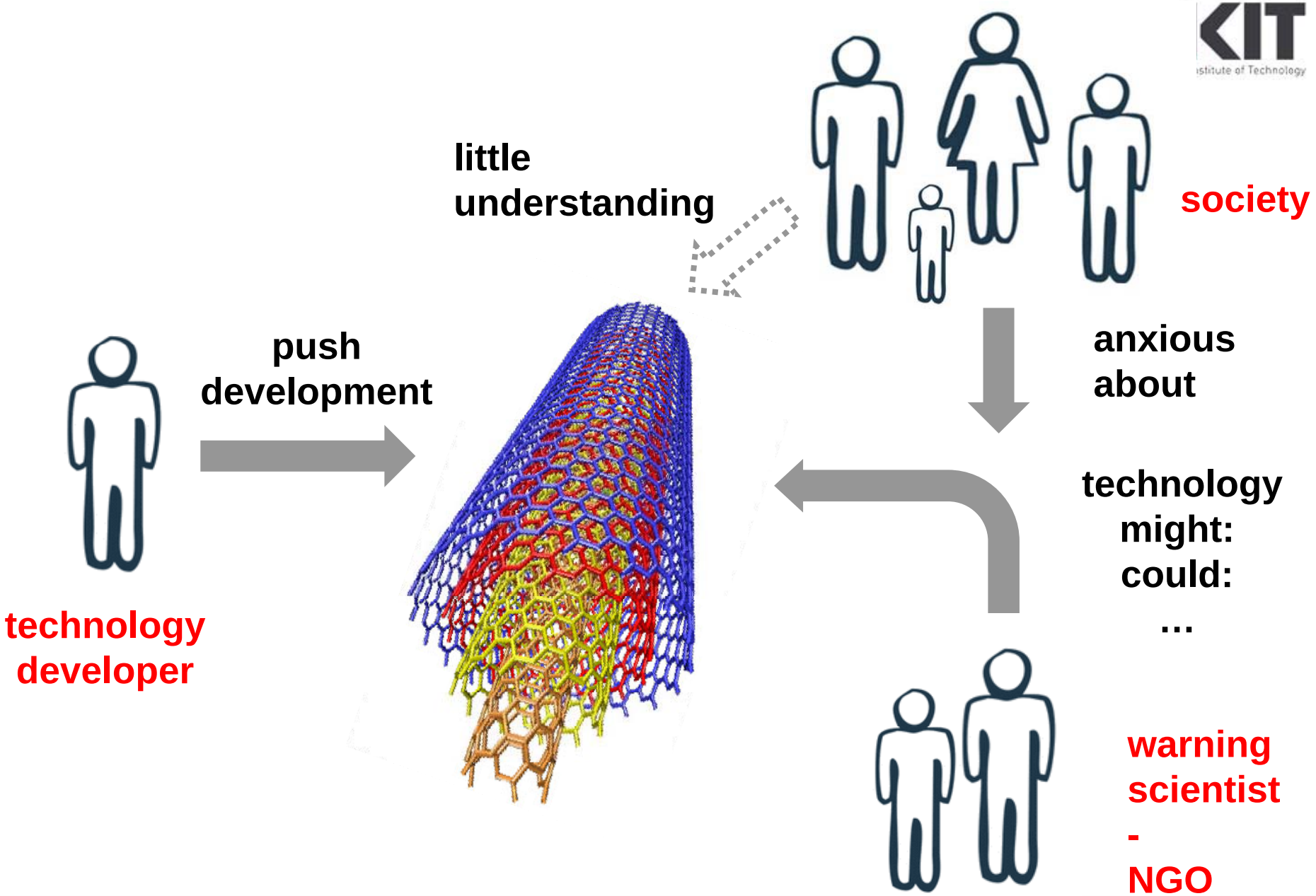
Institute for Technology Assessment and Systems Analysis

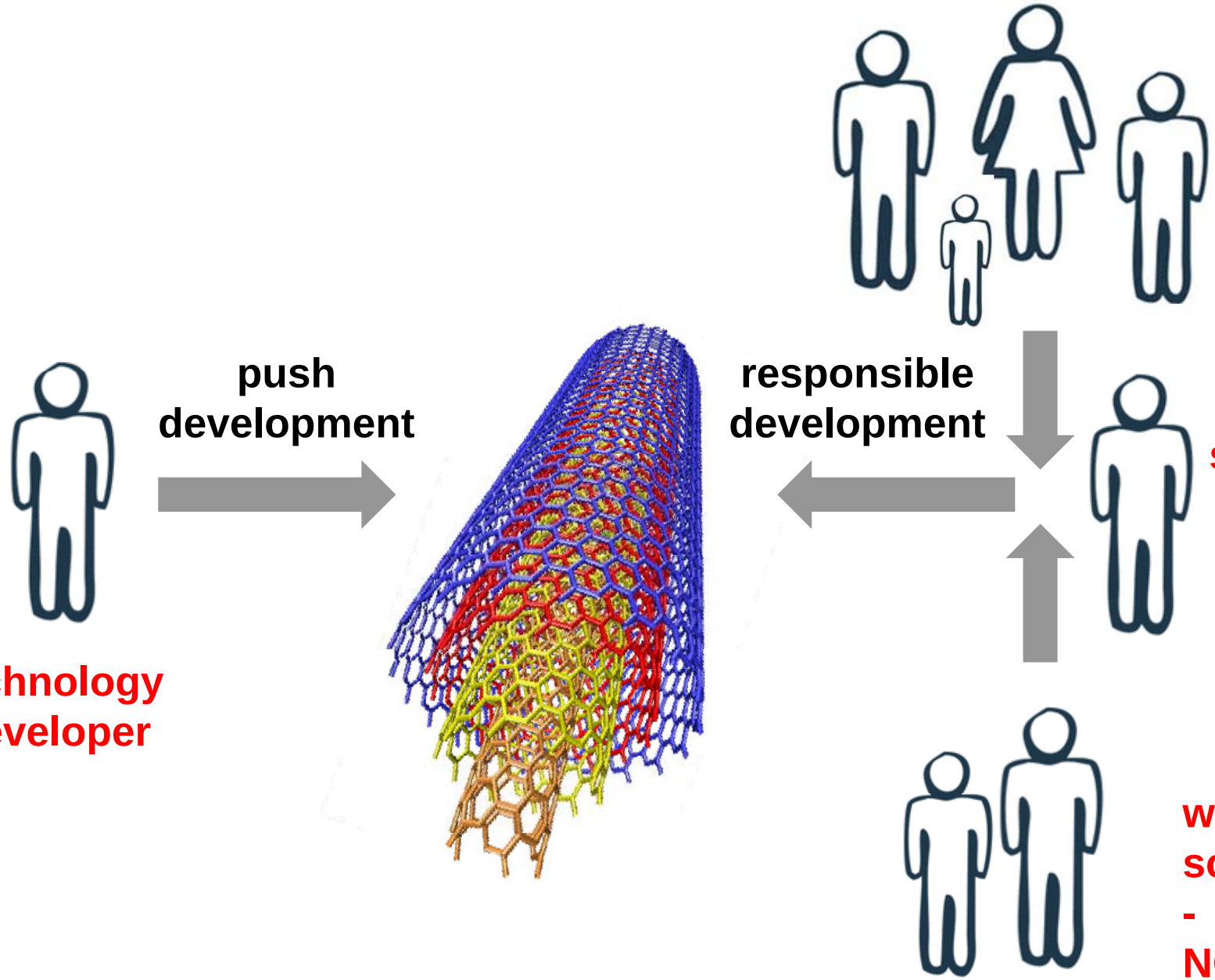
Problems with emerging technologies

- Clear scientific evidence for (environmental or human) damage or risks are very time consuming
- New technologies spreading much faster in multiple application fields than regulation of the technology can take place to mitigate their impacts and risks
- Regulations based on “state of the art” knowledge. Precautionary principle often not applied.

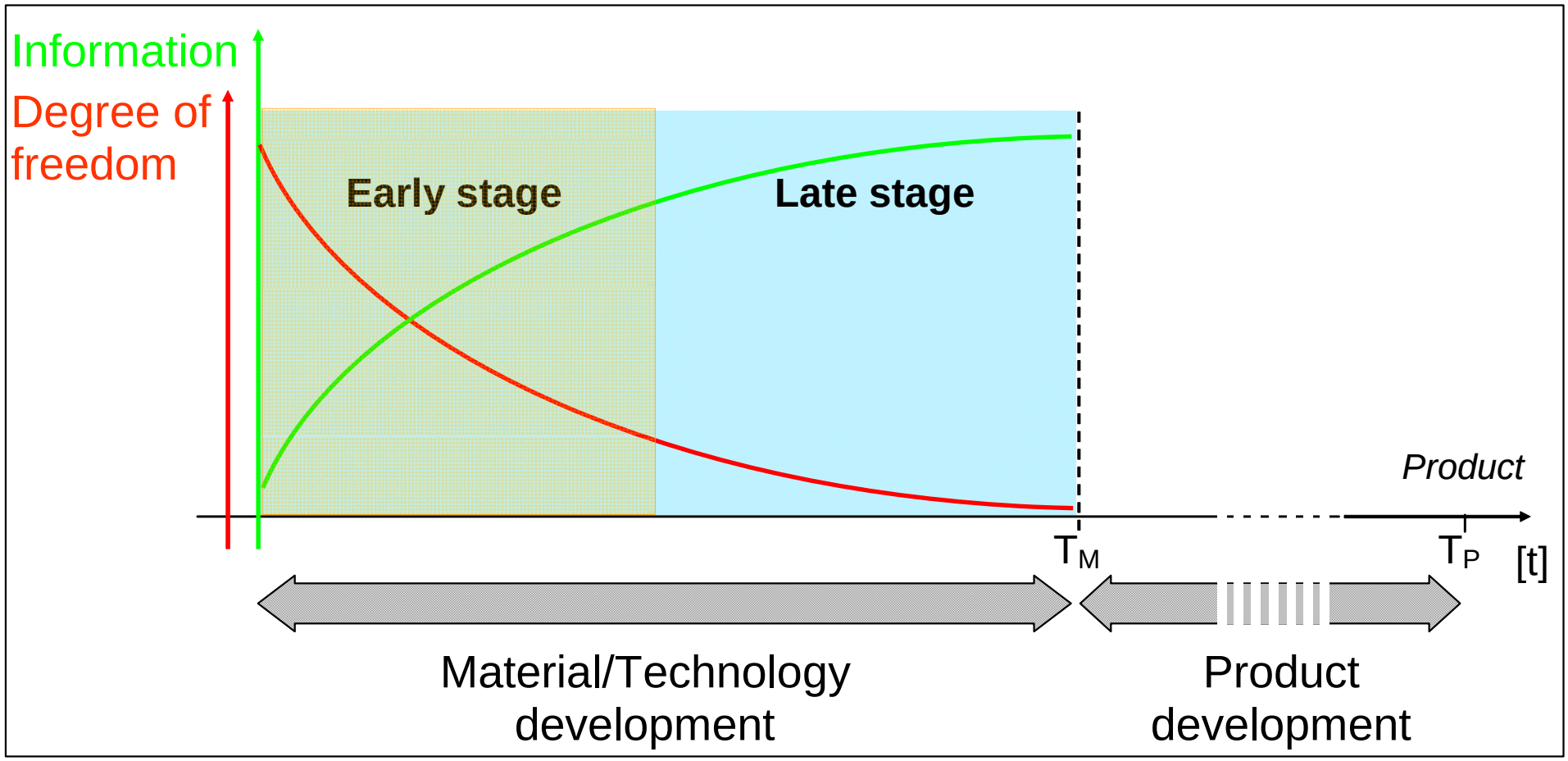
Solution?

Integration of CTA like aspects into the development phase of new and emerging technologies to mitigate their risks


little
understanding
society
push
development
anxious
about
technology
might:
could:
...
technology
developer
warning
scientist
-
NGO


society
push
development
responsible
development
scientist
SA/TA
technology
developer
warning
scientist
-
NGO

Early development phase

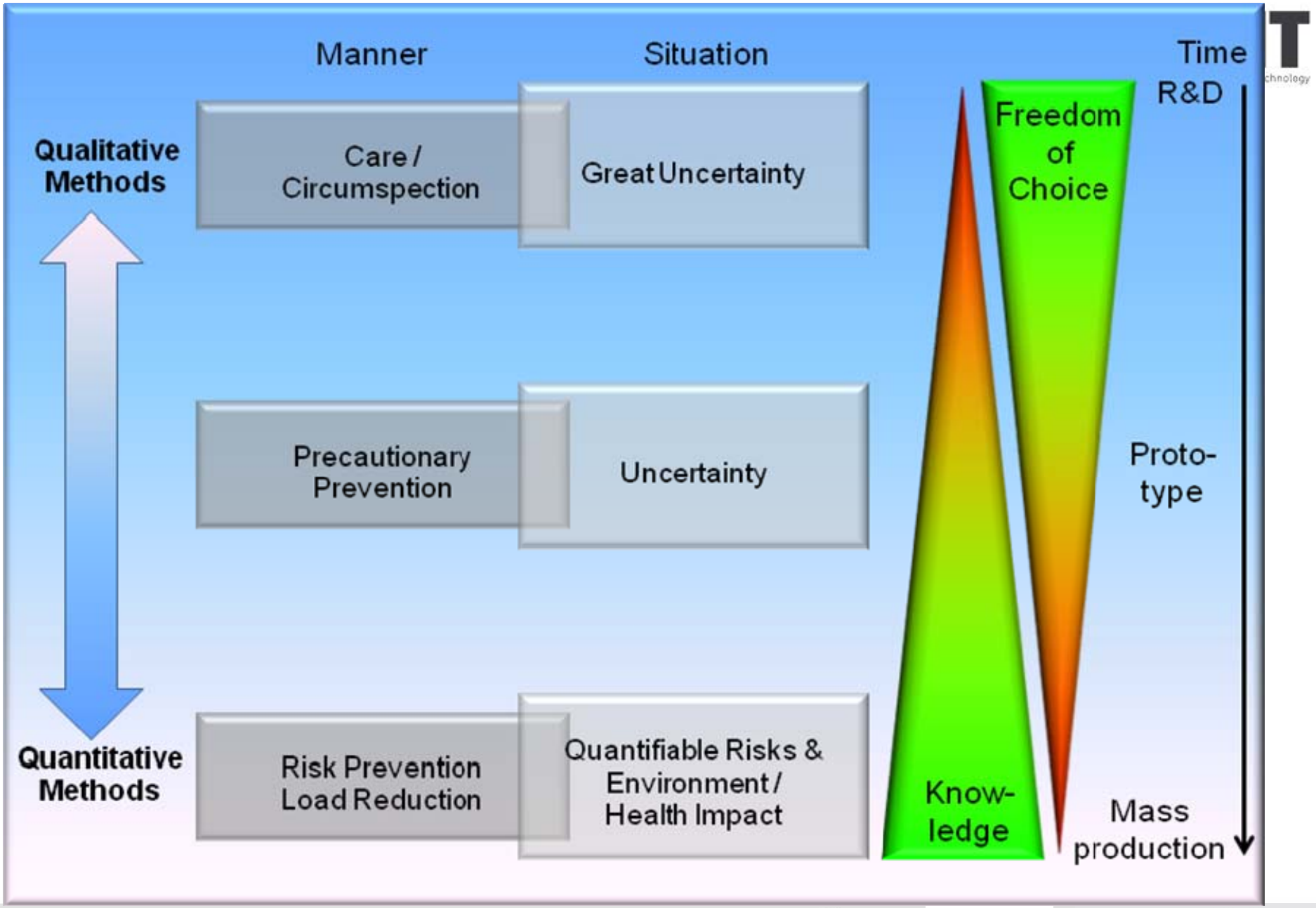


Early development phase of nano objects

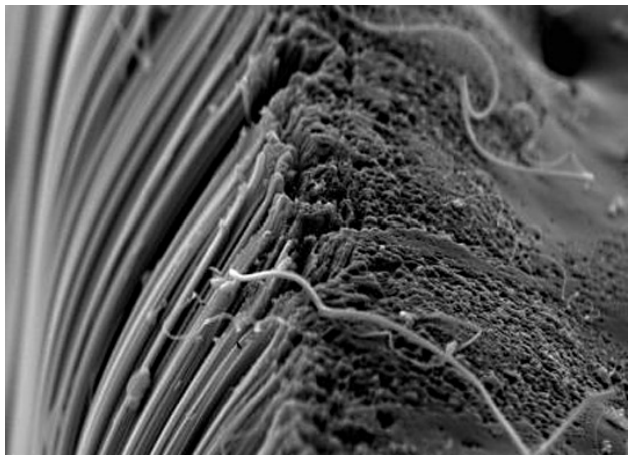
- 80% of nano objects development takes place in small sized companies
- Production rate of nano objects in the range of mg, g, seldom kg or t
- Low level of process automatisation (high degree of manual work)
- Seldom specific application fields are addressed

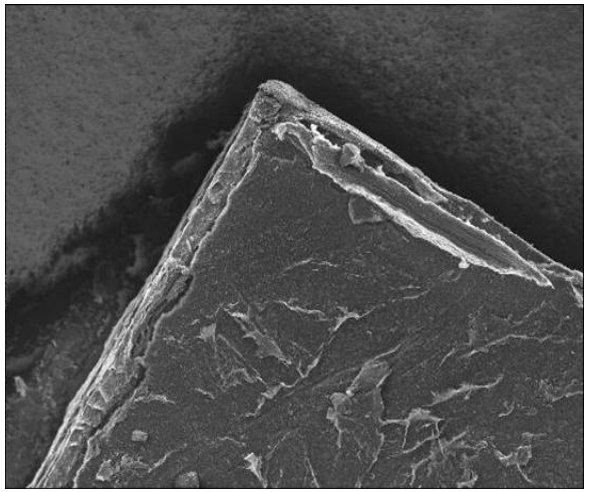
Goal of companies in early stages

- Develop superior technical performance
- Increase competitiveness
- Be first on the market
- Reduce environmental burdens
- Prevent potential negative implications for society
  - ➢ Minimize environmental/human risks
  - ➢ Minimize innovation risks


Manner
Situation
Time
R&D
Qualitative Methods
Care / Circumspection
Great Uncertainty
Freedom of Choice
Precautionary Prevention
Uncertainty
Proto-type
Quantitative Methods
Risk Prevention Load Reduction
Quantifiable Risks & Environment / Health Impact
Know-ledge
Mass production

CNT Papier Produktion





New Materials / Technologies

Nano Materials/ Technologies

“Unknown effects”

- Nano particle (CNT) effect on human health
- Nano particle (CNT) effect on environment

“Unknown effects”

Precautionary Principle

"the release of nanoparticles to the environment [should be] minimized until these uncertainties are reduced."

The British Royal Society and the Royal Academy of Engineering 2004

Optimisation

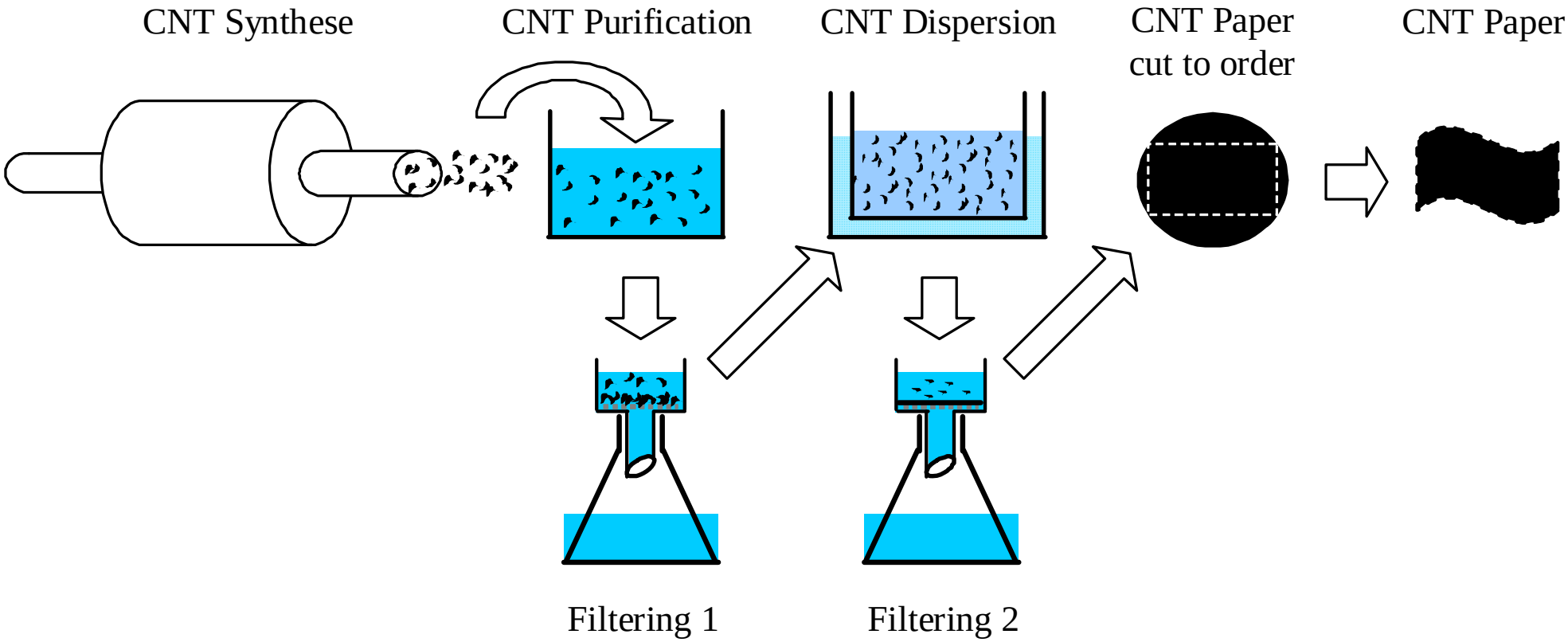
Nano Materials/ Technologies

Carbon Nanotube Paper Production

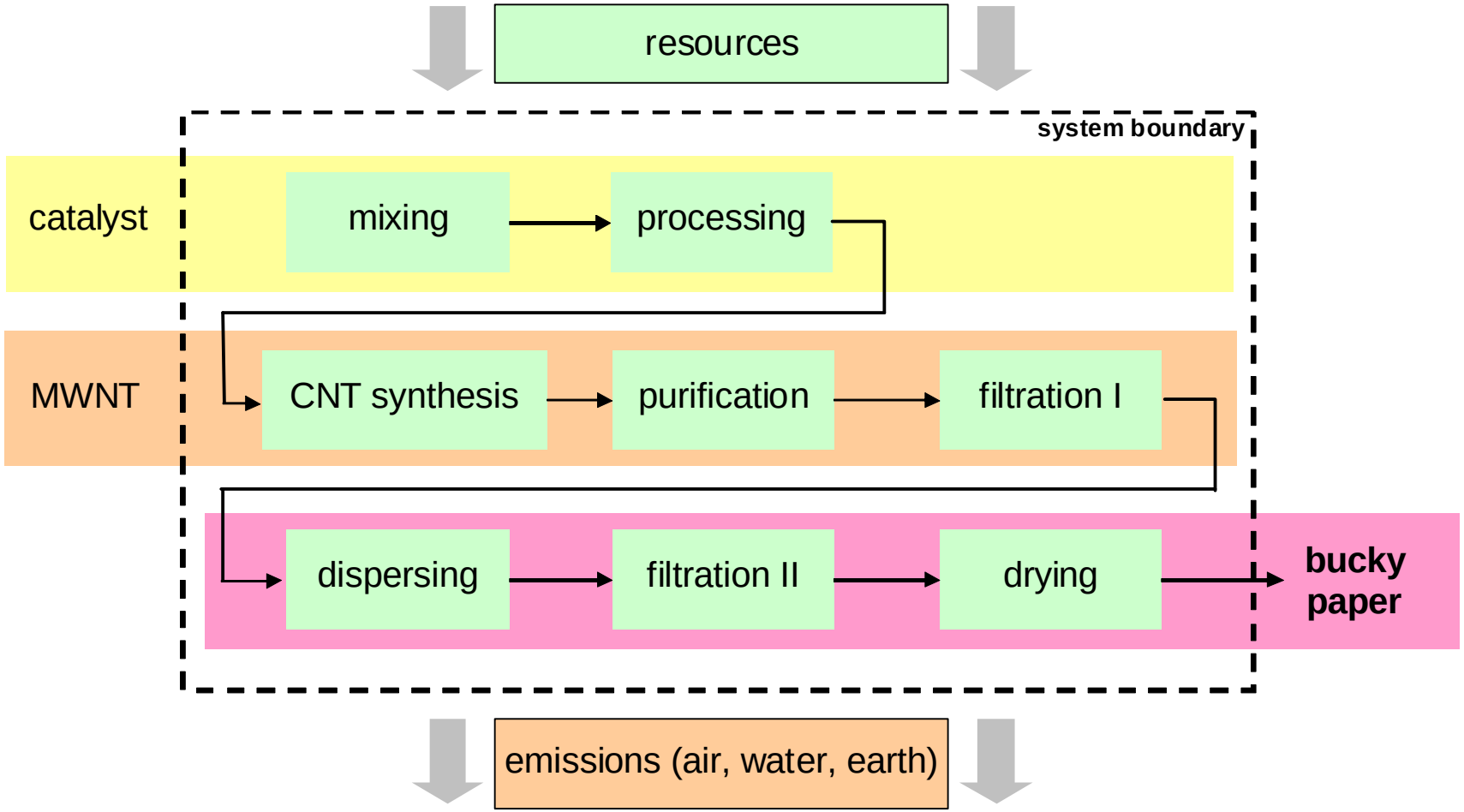
CNT-Paper (Bucky Paper)
Potential Fields of Application

- artificial muscles
- lightweight heating system
- lightweight cooling system
- light absorbent media
- nano filtration
- electric shield
- anode for Li-ion battery (SWNT)
- ….

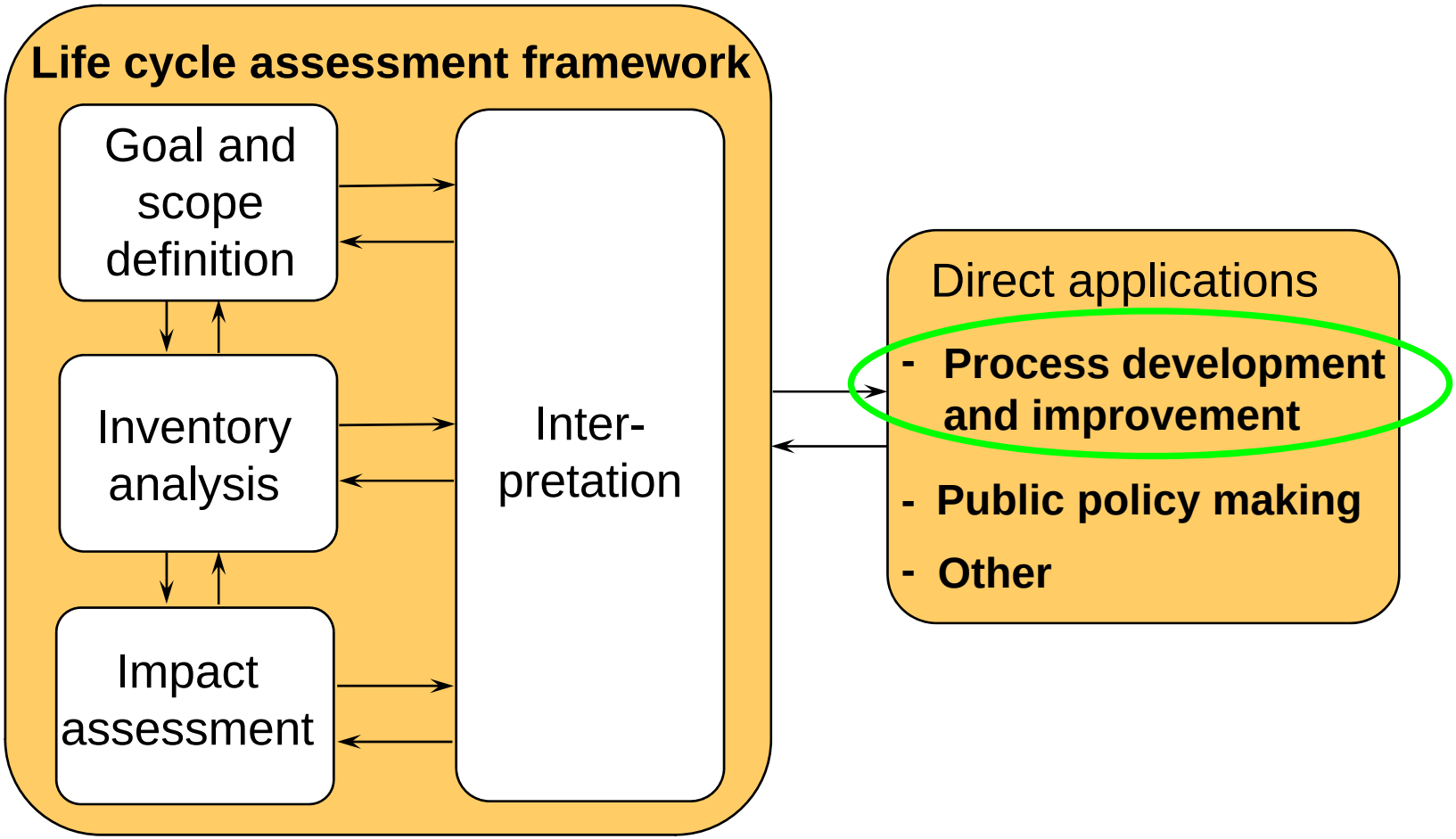
Manufacturing CNT-Paper (Bucky Paper)



System Boundaries for Economic and Ecological Investigations



Ecological Investigation



Literature: DIN EN ISO 14040 Life cycle assessment

Life Cycle Assessment

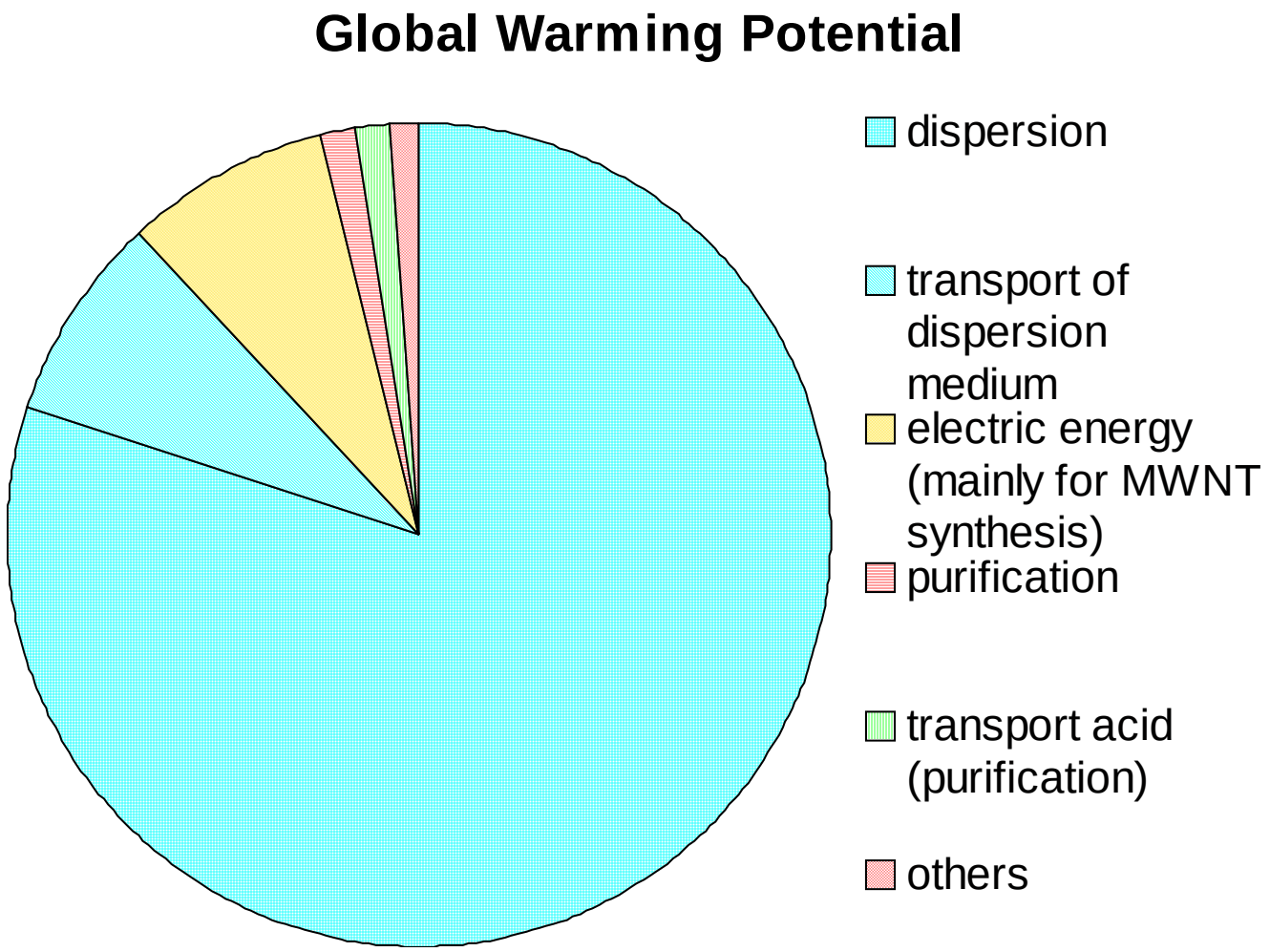
- System boundary: gradle to gate
- Goal: identification of ecological hot spots within the whole production chain of CNT-paper production
- Impact assessment method: CML
  not considered:
  - human toxicity (of nano particle)
  - eco toxicity (of nano particle)

Life Cycle Assessment
Selected Impact Indicator

- Global Warming Potential (GWP) [kg CO_2-equivalents] (CO_2, CH_4, ...)

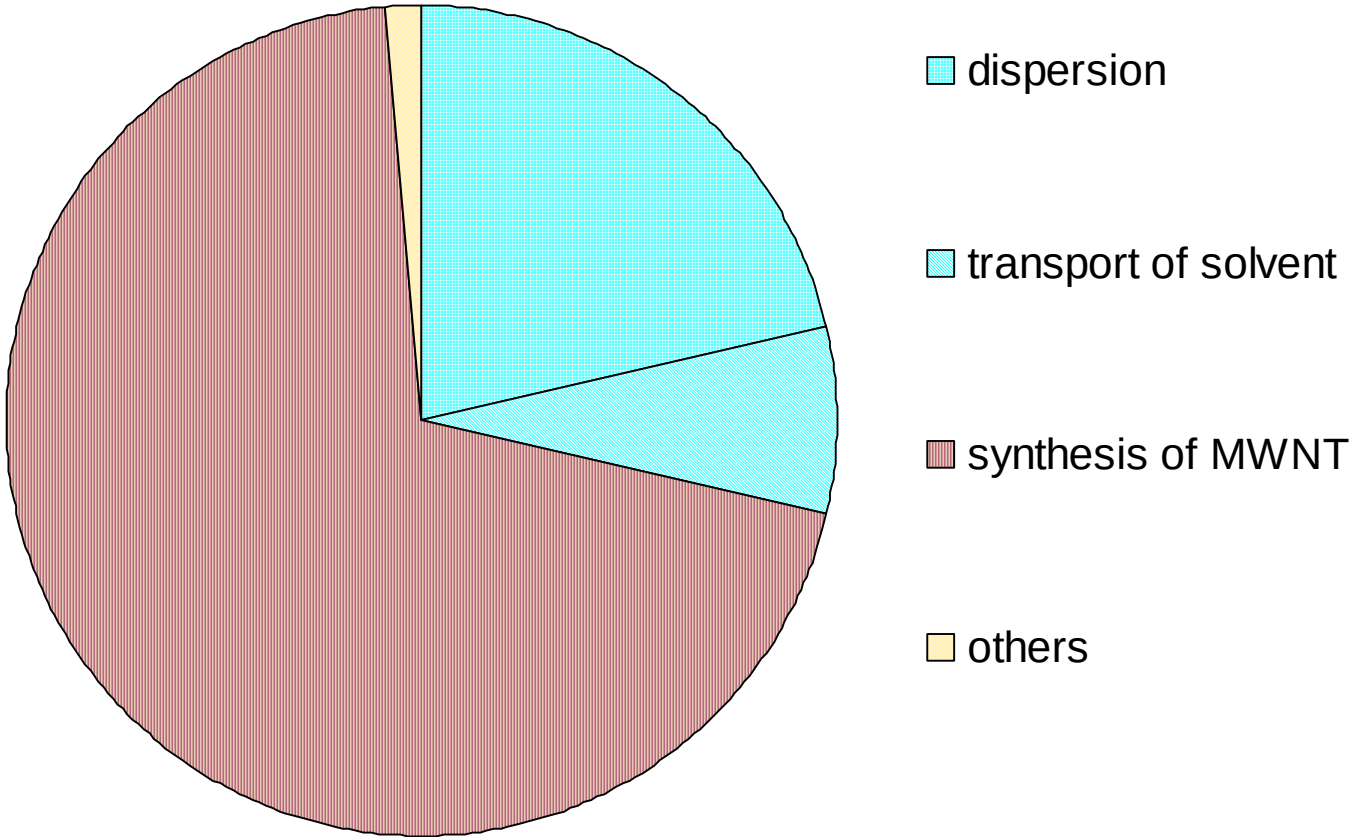
- Photochemical oxidation [kg Ethylen-equivalents] “summer smog”

Environmental Impact



Environmental Impact

Photochemical Oxidation



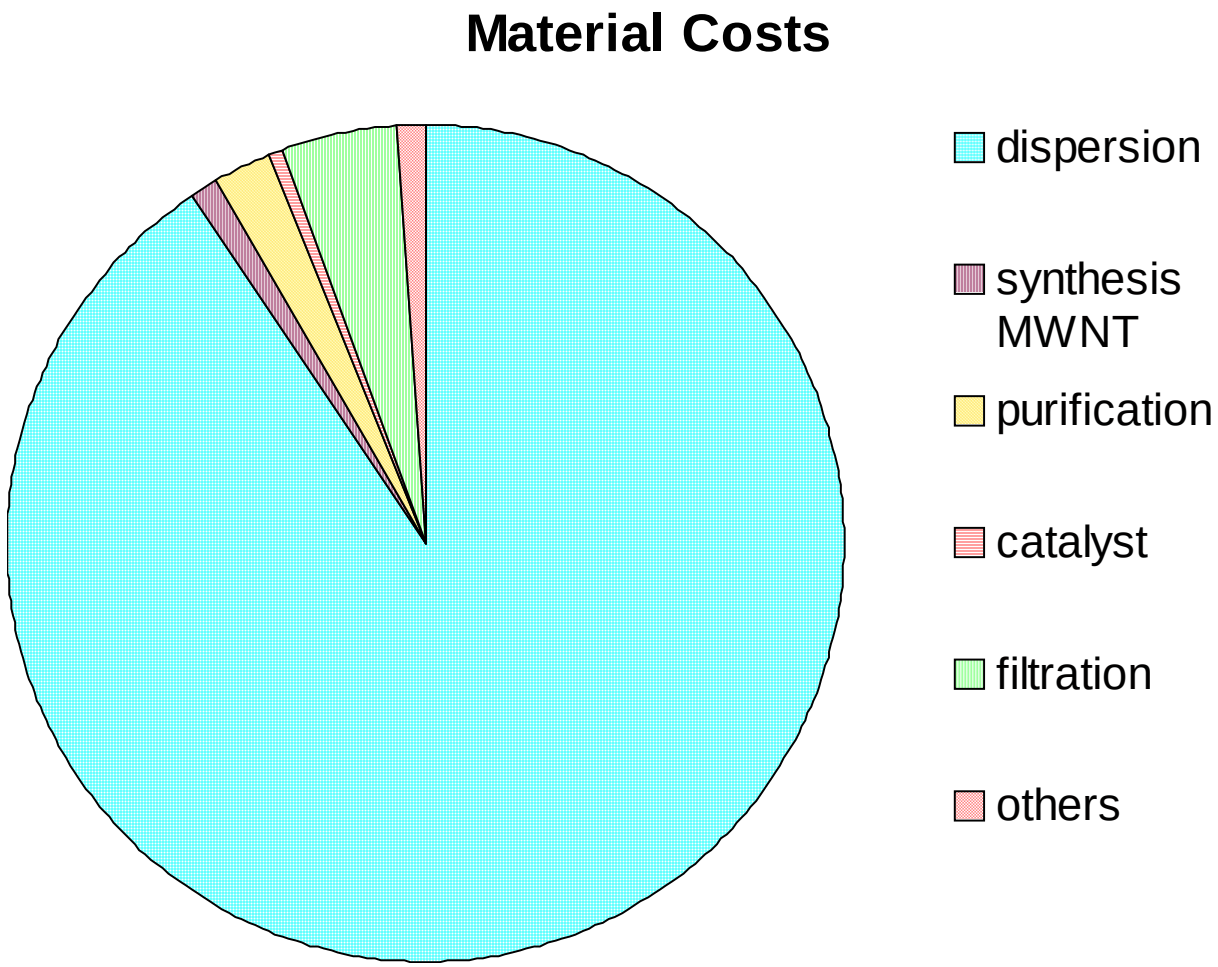
Economic Analysis

System boundaries:

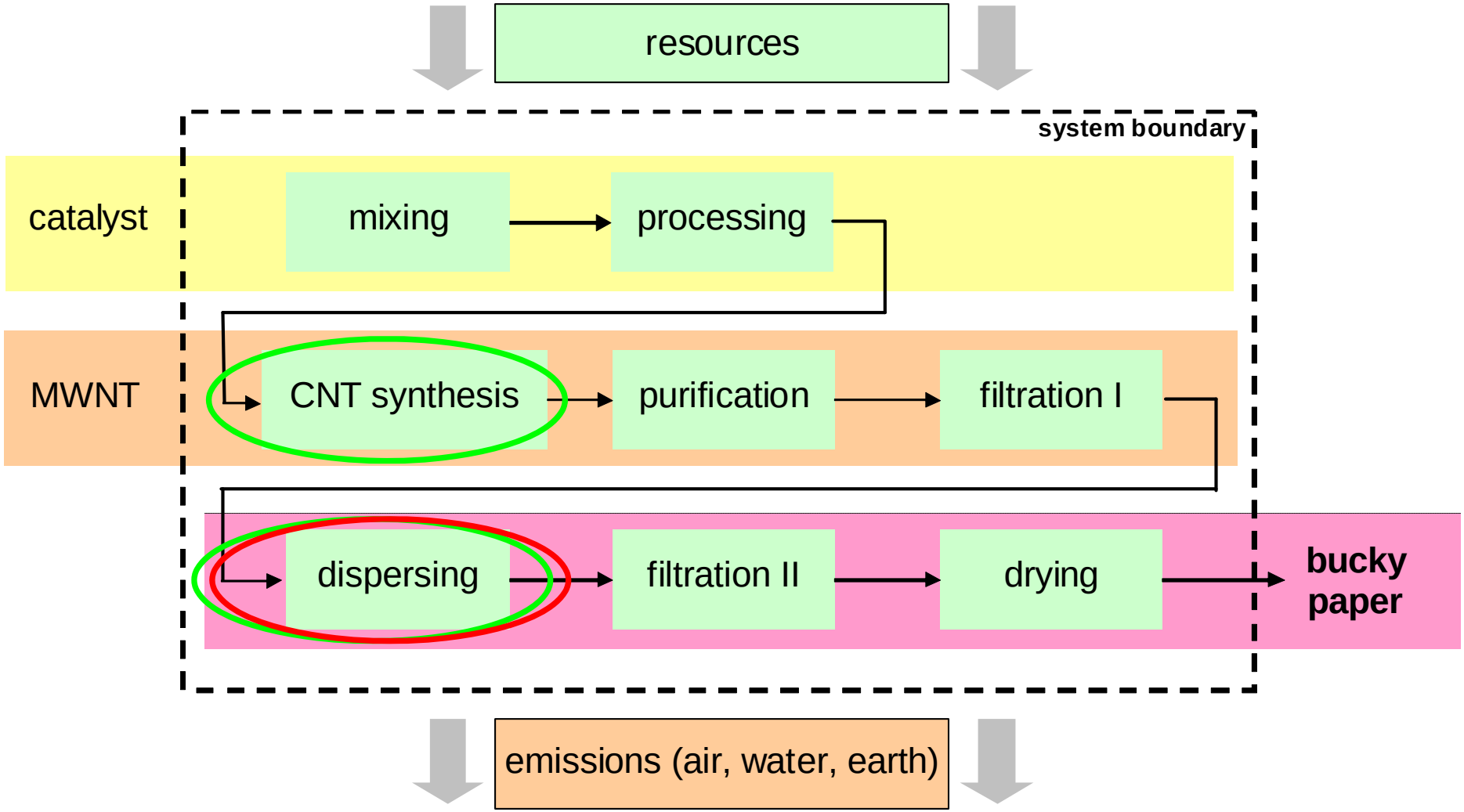
production costs

-> focus: material costs

Economic Analysis



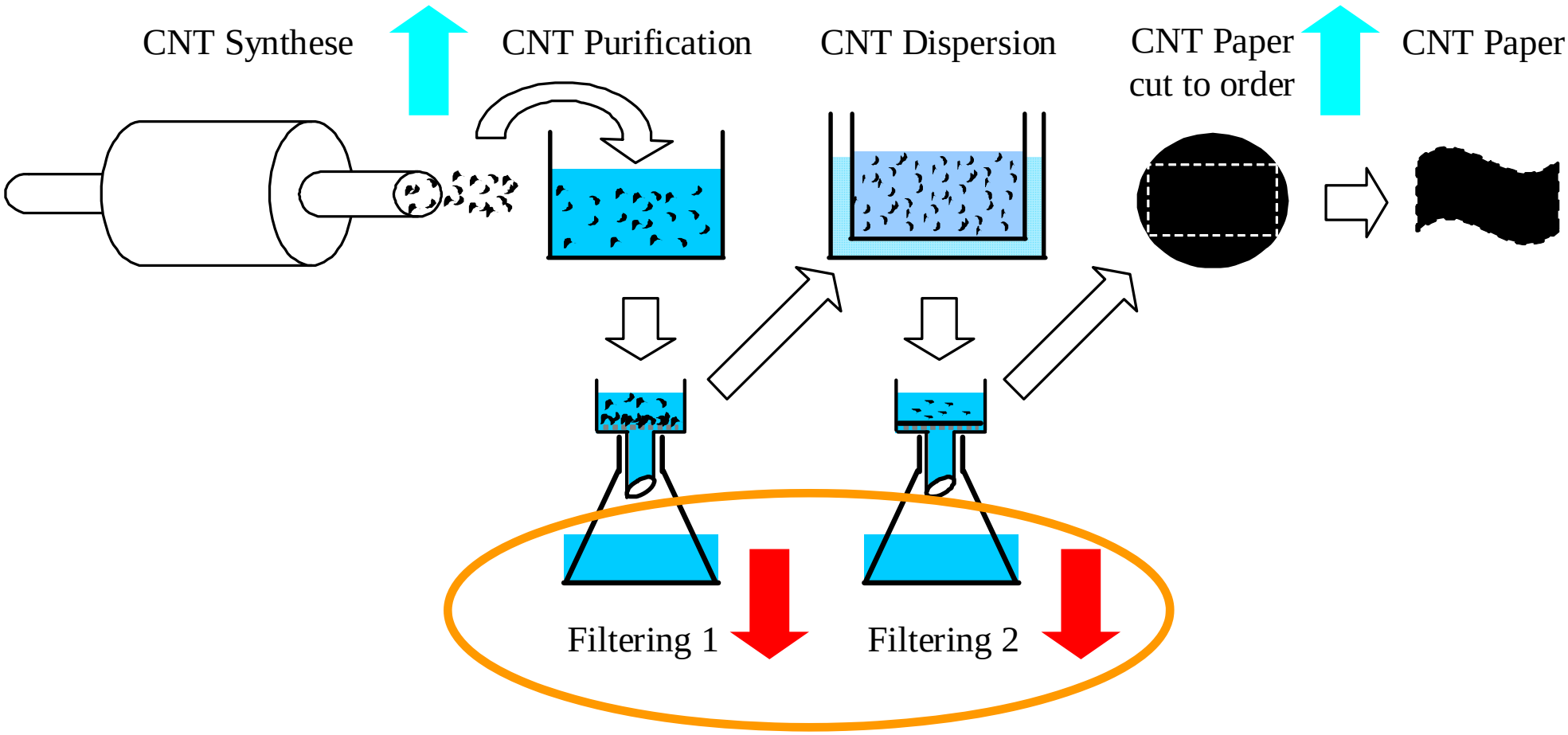
Hot spots


resources
system boundary
catalyst
mixing
processing
MWNT
CNT synthesis
purification
filtration I
dispersing
filtration II
drying
bucky paper
emissions (air, water, earth)

Optimisation strategies

- **Quality bucky paper**
- **Economic aspects**
- **Ecological aspects (LCA)**

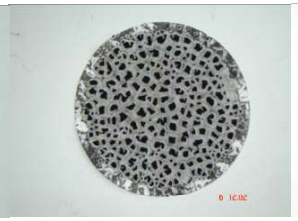
Nano Particle Emissions Sources



Optimisation strategies

- **Quality bucky paper**
- **Economic aspects**
- **Ecological aspects**
- **Emissions of nano particle (to water)**

Optimisation strategies

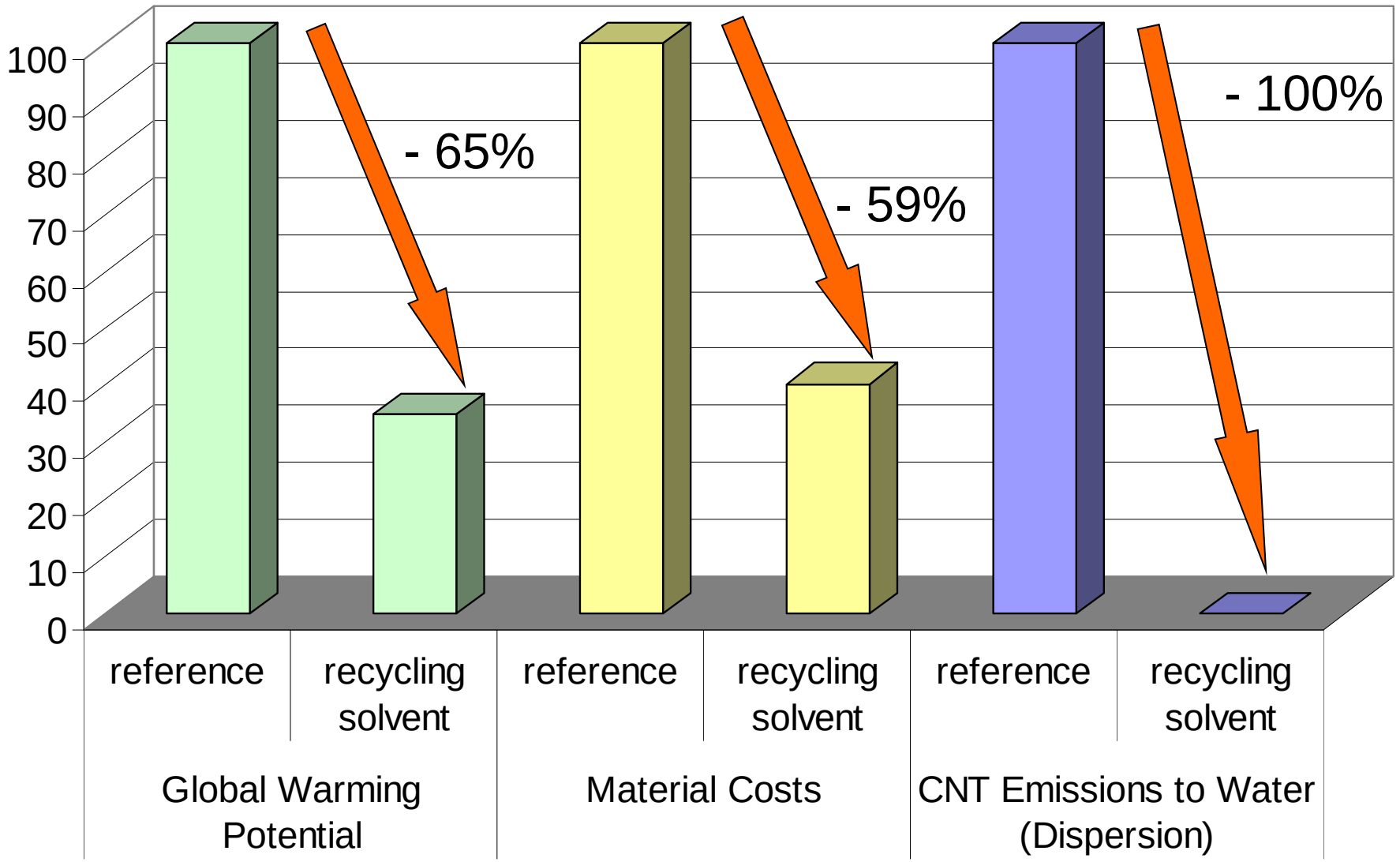
100% Solvent (Reference)	Solvent replacement by 100% alternative solvent	Solvent replacement up to 30% by water	Solvent replacement by 100% water/tensideX1 mixture	Solvent replacement by 100% water/tensideX2 mixture	Solvent replacement by 100% water/tensideX3 mixture	Recycling of reference solvent
						
A	A/B	B/C	B	C	C	A

Optimisation strategies

	100% Solvent (Reference)	Solvent replacement by 100% alternative solvent	Solvent replacement up to 30% by water	Solvent replacement by 100% water/tensideX1 mixture	Solvent replacement by 100% water/tensideX2 mixture	Solvent replacement by 100% water/tensideX3 mixture	Recycling of reference solvent
Quality bucky paper	A	A/B	B/C	B	C	C	A
Economic profile	C	A/B	B	A/B	A/B	C	A/B
Ecological profile	C	C	B	A/B	A/B	A/B	A/B
CNT emissions (to water)	C	C	C	C	C	C	A/B

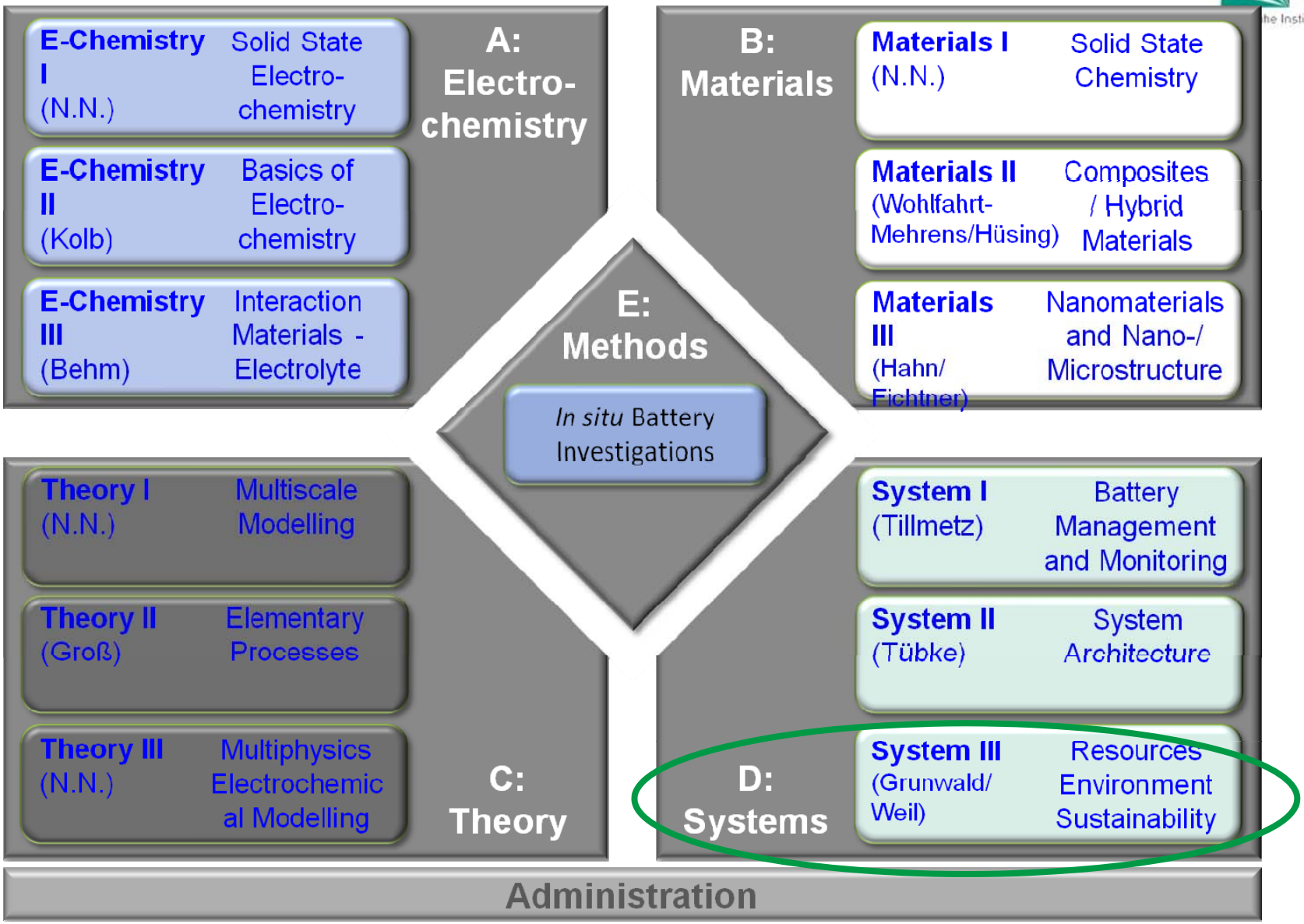
Advantages Option „Recycling Solvent“

- Up 70 % of the solvent is recyclable
- Low efforts for reprocessing of recycled solvent
- No detectable quality problems of bucky paper production (continuous closed loop recycling of solvent is under investigation)
- Economic and ecological savings by reduced consumption of primary solvent
- Reduced efforts for transport und storage of solvent
- No nano particle emissions to water (dispersion process)


100
90
80
70
60
50
40
30
20
10
0
- 65%
- 59%
- 100%
reference
recycling solvent
reference
recycling solvent
reference
recycling solvent
Global Warming Potential
Material Costs
CNT Emissions to Water (Dispersion)

Integration of sustainability aspects into the development of electrochemical energy storage

Founded in 2011


A: Electro-chemistry
E-Chemistry I (N.N.) Solid State Electro-chemistry
E-Chemistry II (Kolb) Basics of Electro-chemistry
E-Chemistry III (Behm) Interaction Materials - Electrolyte
B: Materials
Materials I (N.N.) Solid State Chemistry
Materials II (Wohlfahrt-Mehrens/Hüsing) Composites / Hybrid Materials
Materials III (Hahn/ Fichtner) Nanomaterials and Nano-/ Microstructure
E: Methods
In situ Battery Investigations
C: Theory
Theory I (N.N.) Multiscale Modelling
Theory II (Groß) Elementary Processes
Theory III (N.N.) Multiphysics Electrochemical Modelling
D: Systems
System I (Tillmetz) Battery Management and Monitoring
System II (Tübke) System Architecture
System III (Grunwald/ Weil) Resources Environment Sustainability
Administration

Conclusions

- New and emerging technologies are pushed in various application fields
- Scientific evidence about potential negative implications (impact on human health and environment) are complex and time consuming
- Regulation take place often too late
- Between moratorium and pushing of the technology there is a small pathway of responsible development
- The early development and design phase has to broaden fur further aspects (beyond technology end economics)

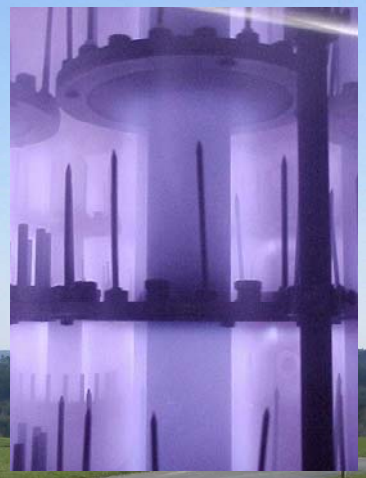
Conclusions

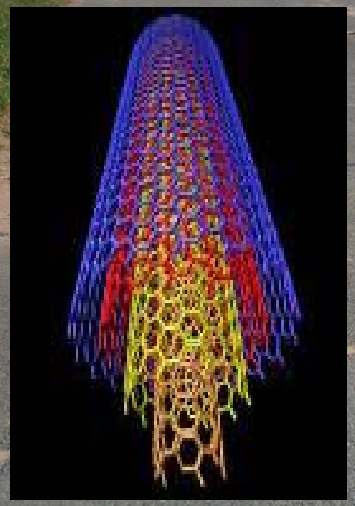
- Scientist in the field of CTA and SA can search for early warnings from science/NGOs and concerns of society, to consider such issues within the development phase in a close cooperation with the technology developer itself.
- Presented approach :
  - The precautionary principle has to be translated into development goals
  - The combination of qualitative and quantitative methods seems to be very advantageous in early development phases
  - After the technology reaches a higher maturity, the whole life cycle has to be considered

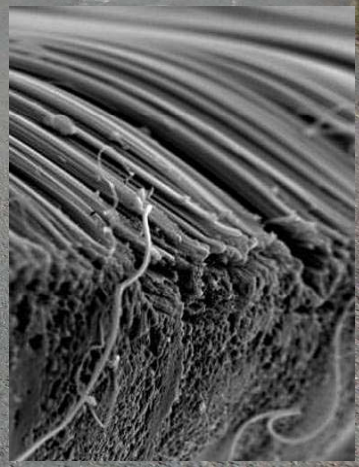
Literature

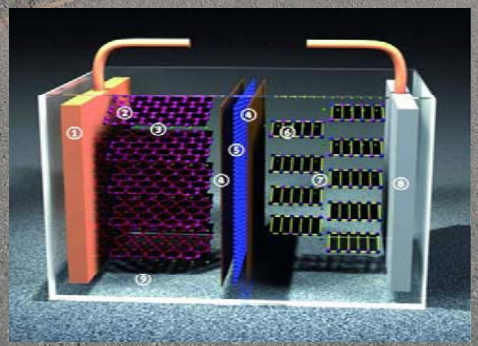
- **Weil, M.**
  Consideration of the precautionary principle - the responsible development of nano technologies. In: Hesselbach, J.; Herrmann, Chr. (Hrsg.): Glocalized solutions for sustainability in manufacturing. Springer 2011, pp. 185-188.
- **Weil, M.**
  Systems analysis in the early phase of technology development. Responsible development and production of carbon nanotube paper. In: Decker, M.; Grunwald, A.; Knapp, M. (Hrsg.): Der Systemblick auf Innovation. Technikfolgenabschätzung in der Technikgestaltung. Berlin: edition sigma 2012, S. 301-312
  (Gesellschaft - Technik - Umwelt, Neue Folge 16)
- **Weil, M.; Simon, B.; Dura, H.; Baumann, M.; Zimmermann, B.**
  Nano materials for the next generation of lithium-based batteries. A prospective systems analysis. Nanofair, Dresden, 12.-13.06.2012
- **Weil, M.; Dura, H.; Simon, B.; Baumann, M.; Zimmermann, B.; Ziemann, S.; Lei, C.; Markoulidis, F.; Lekakou, T.; Decker, M.**
  Ecological assessment of nano-enabled supercapacitors for automotive applications. IOP Conf. Series: Materials Science and Engineering 40(2012)012013

Responsible development of new and emerging technologies









Thank You

Nano objects reach water pathway

Silver Nanoparticles May Be Killing Beneficial Bacteria In Wastewater Treatment

ScienceDaily (Apr. 30, 2008) — Too much of a good thing could be harmful to the environment. For years, scientists have known about silver's ability to kill harmful bacteria and, recently, have used this knowledge to create consumer products containing silver nanoparticles. Now, a University of Missouri researcher has found that silver nanoparticles also may destroy benign bacteria that are used to remove ammonia from wastewater treatment systems.

No threat from nanosilver in wastewater treatment

Editor | 23/02/2011 | 0 Comments

EMPA researcher claims that nanosilver in sewage doesn't pose a threat to ecosystems.

EMPA researcher Bernd Nowack has discussed the implications of the latest studies on nanosilver in wastewater treatment plants in the journal 'Science.' (Nanosilver Revisited Downstream by Bernd Nowack, Science, 2010, Vol. 330 no. 6007, pp. 1054-1055, DOI: 10.1126/science.1198074). EMPA is an interdisciplinary research and services institution for material sciences and technology development based in Switzerland.

Nano-Objects in Waste

Science for Environment Policy

Nanoparticles present in residues of waste incineration plant

The use of nanomaterials in consumer goods is growing, as is their presence in waste. A new study is the first to follow the fate of engineered nanoparticles through the entire waste incineration chain. The results indicate current filter technology is effective in removing nanoparticles from flue gas, but that nanoparticles also bind to residues, such as fly ash and slag, which eventually end up in landfill.

Source: Walser, T., Limbach, L.K. Robert Brogioli, R. *et al.* (2012) Persistence of engineered nanoparticles in a municipal solid-waste incineration plant. *Nature Nanotechnology*. 7: 520–524 doi:10.1038/nnano.2012.64.