Broadening our view on nanomaterials:

Highlighting potentials to contribute to a sustainable materials management in preliminary assessments

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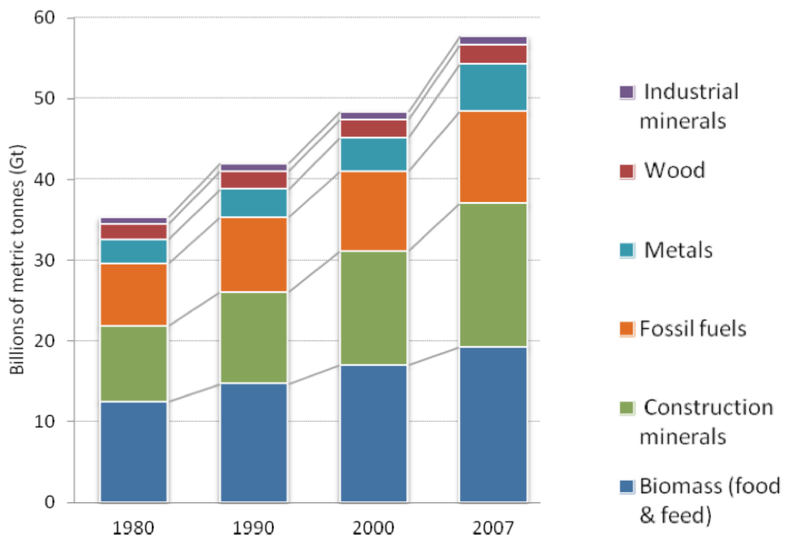
Outline

- Background
- Role of Nanotechnology
- Sustainable Materials Management
- Framework for preliminary assessment
- Case studies
- Conclusion

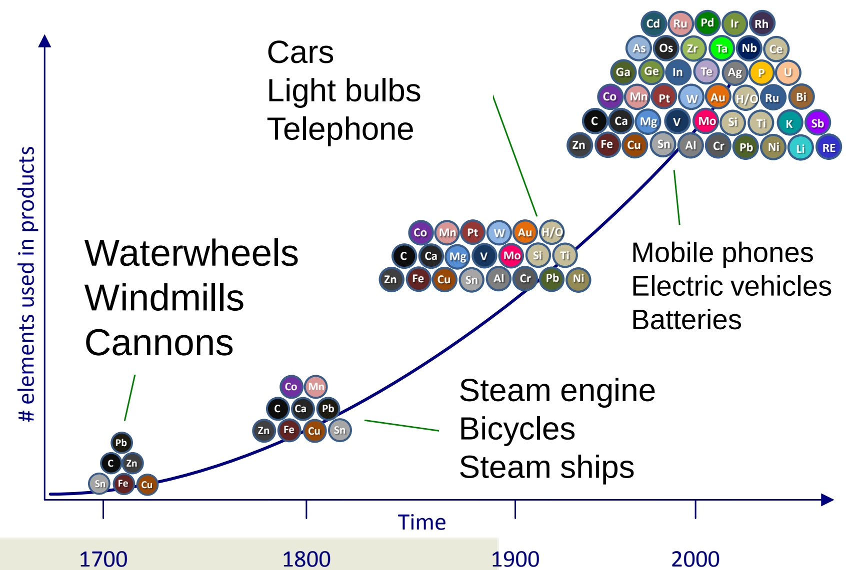
Background and need for sustainable Materials Management

- Economic growth is related with increasing resource consumption

Global extraction of materials resources (OECD 2008)



Increasing use of a variety of elements



by courtesy of Till Zimmermann; adapted from Reuter et al. (2013)

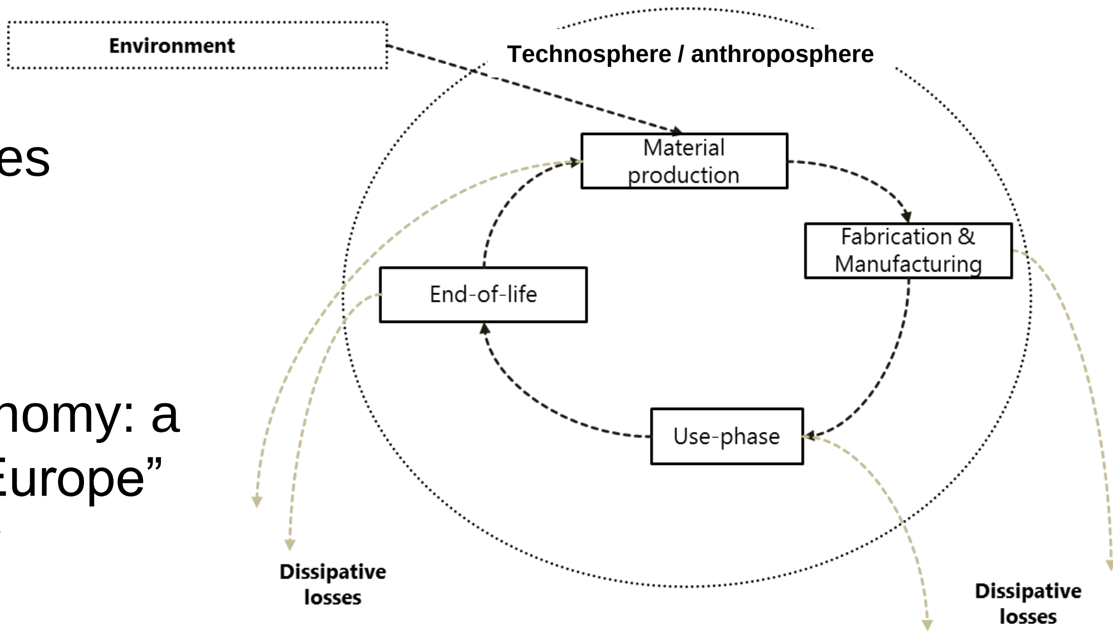
Role of nanotechnology

- Nanotechnology offers many opportunities
  - New and enhanced functionalities
  - Contribution to higher efficiency (less material per product)
  - …
- …but can also add higher complexity to products
  - Low amount of material
  - Higher variety of materials
  - New challenges in recycling at the end-of-life
- Need for integrating further sustainability aspects in a comprehensive assessment

→ Sustainable Materials Management in preliminary assessments

Sustainable Materials Management

"…approach to **promote sustainable materials use**, integrating actions targeted at **reducing negative environmental impacts** and **preserving natural capital** throughout the **life cycle of materials**, taking into account **economic efficiency and social equity"** (OECD 2010)



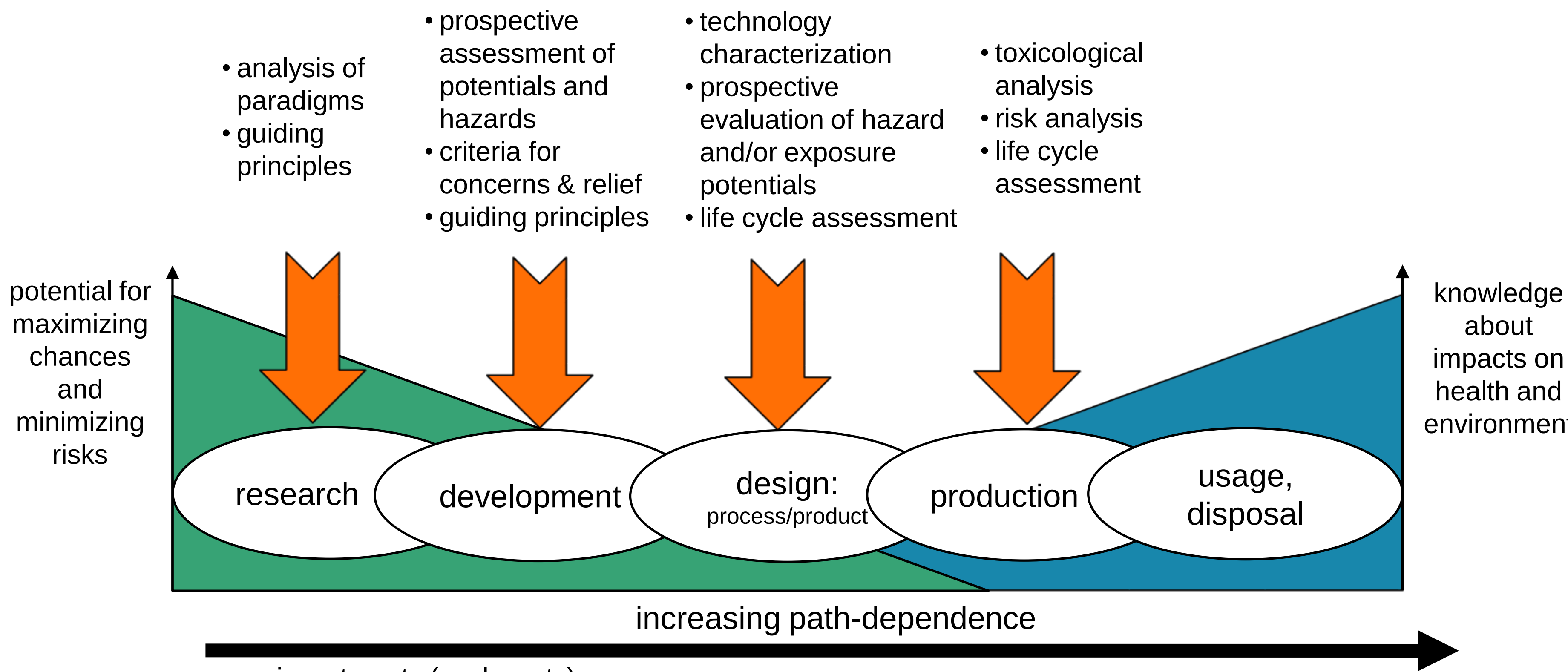
Aiming at:

- Less use of primary resources
- Circular economy
- Entire life cycle

Gained political relevance

- EC: "Towards a circular economy: a zero waste programme for Europe"
- Germany: Circular economy

Challenges in early innovation stages



⇒ investments (sunk costs)
⇒ opportunities and risks increasingly determined by application objectives and contexts

Proposed Framework categories

- Framework categories proposed to consider sustainable materials management:
  - Resource efficiency
  - Criticality
  - Dissipation and Release

Category Resource efficiency

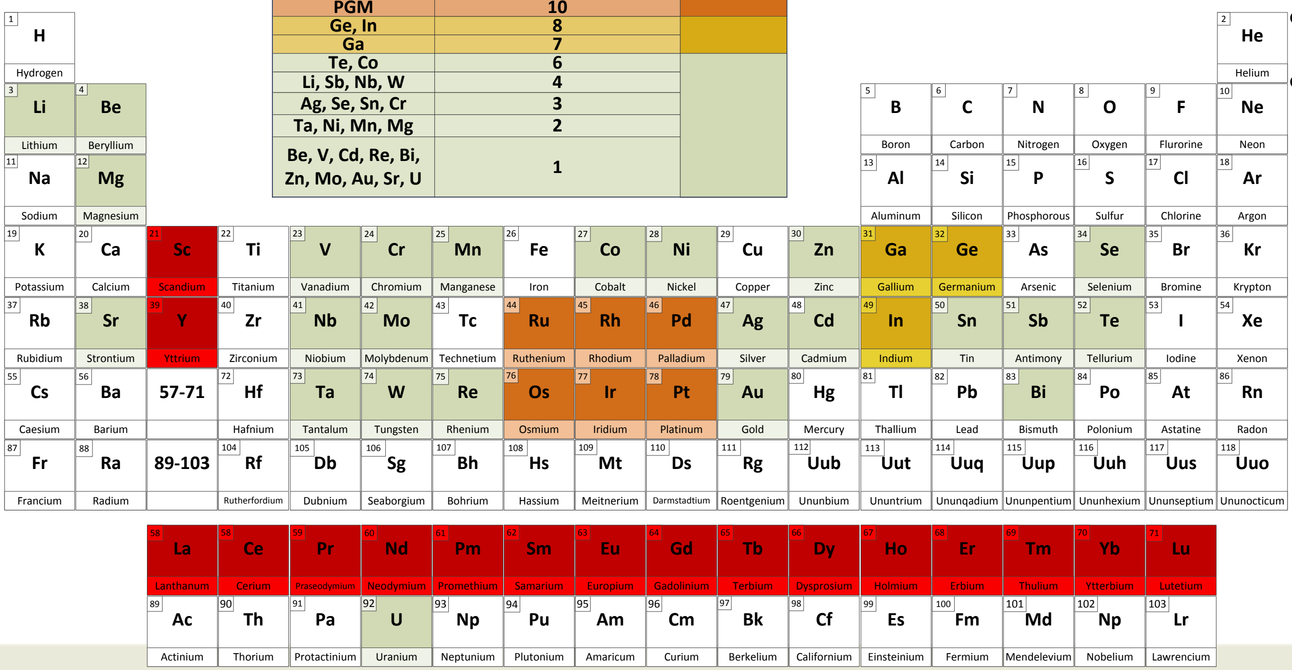
- Different definitions exist
  - Often narrow focus: material efficiency per functional unit

- Here: use of a broader understanding of resource efficiency:
  - Material and energy inputs,
  - Entire product life cycle including recycling, and
  - Related environmental impacts
    (i.e., emission of greenhouse gases, not comprehensively considered).

Category Criticality

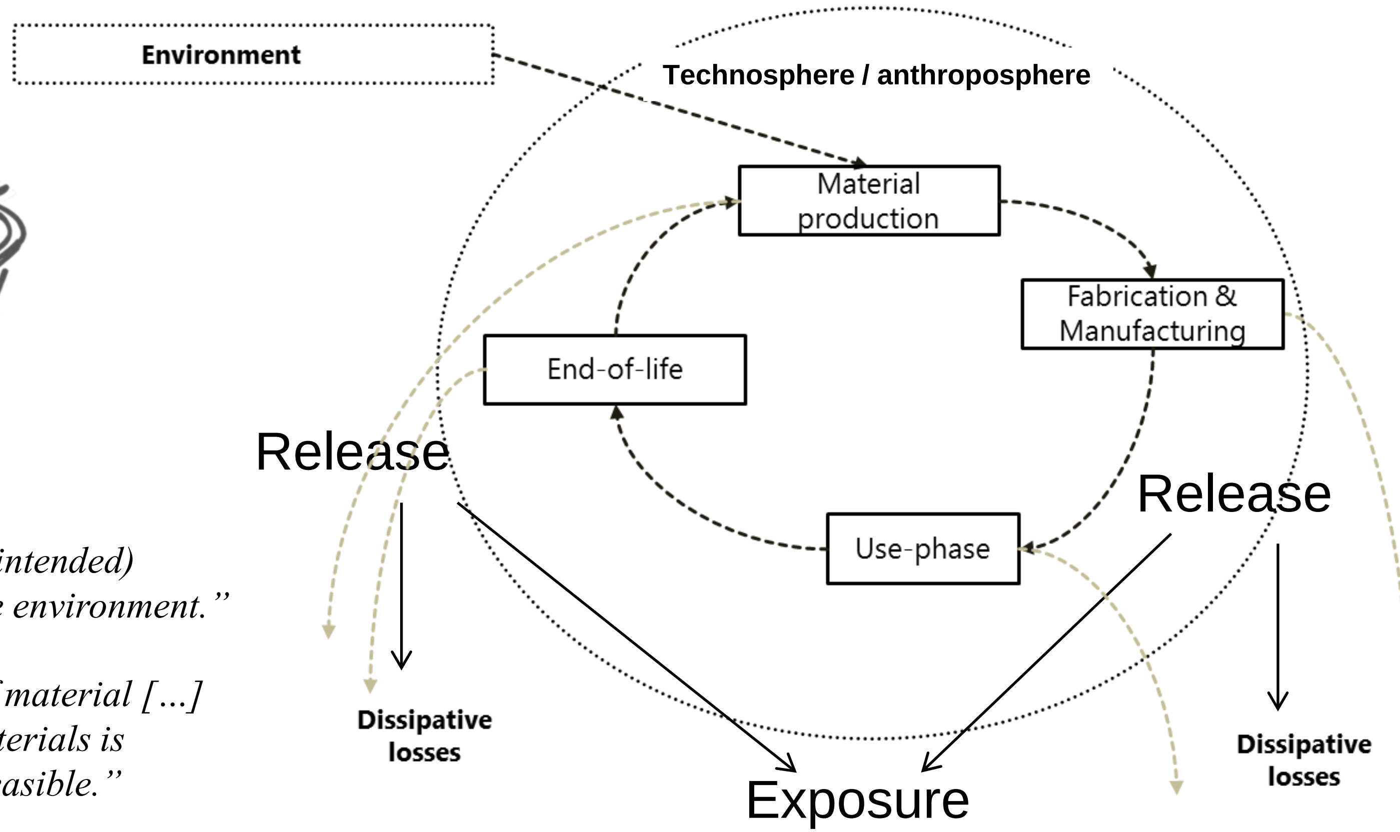
Criticality is commonly understood as a function of a material’s supply risk and its (economic) importance.

Metal	# of criticality considerations	Color
REE	12	
PGM	10	
Ge, In	8	
Ga	7	
Te, Co	6	
Li, Sb, Nb, W	4	
Ag, Se, Sn, Cr	3	
Ta, Ni, Mn, Mg	2	
Be, V, Cd, Re, Bi, Zn, Mo, Au, Sr, U	1	



- Several studies exist
- Differing in
  - Scope
  - Time horizon
  - Methodological aspects

Category Dissipation and Release



"Releases are (intended or non-intended) emissions of a substance into the environment."

"Dissipative losses are losses of material […] such that a recovery of these materials is technically or economically unfeasible."

Scoring in the Framework categories

Inspired by NanoRiskCat (EHS) by Hansen et al. (2014)

- Probably *significant improvement* by applying NM.
- Probably <u>*no*</u> *significant improvement* by applying NM.
- Probably *significant deterioration* by applying NM.
- *Insufficient information* available for a reasonable categorization, further research needed

First indication given for the category, but *further investigations* for confirmation *needed.*

Scoring in the categories:

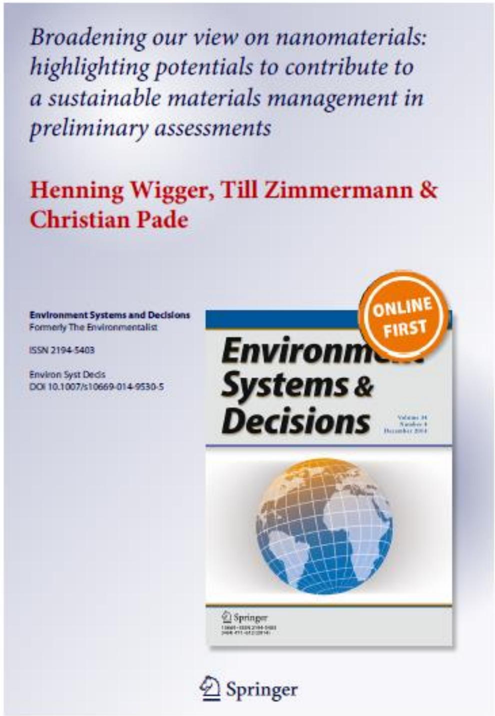
- Analogous assumptions
- Precautionary manner

Focus on the product

Wigger et al. (2014)

Case studies

- **Photovoltaics**
- Permanent magnets (substitution of rare earth elements)
- Magnetic resonance imaging (substitution of gadolinium)
- Concrete (substitution of cement)



Preliminary evaluation

Photovoltaic	**Resource efficiency**	**Criticality**	**Dissipation & Release**
Improved solar cell by plasmonic NP (Au or Ag)	● green (hatched)	● yellow	● red (hatched)
Rare earth elements-doped nanocrystals solar cells	● grey	● red	● red (hatched)
Si-nanowires arrays in thin film solar cells	● green (hatched)	● yellow	● yellow
Substitution of gallium and indium with zinc and tin nanocrystals in thin film solar cells	● yellow (hatched)	● green (hatched)	● yellow (hatched)

Wigger et al. (2014)

Conclusions

- Need to broaden the view on nanomaterials
- Proposed framework for orientation can be used especially in preliminary assessments
- Dissipation and release not improved at all in the considered case studies
- Future studies should
  - also include other sustainable aspects (societal, economical) and
  - consider a weighting of the categories

Discussion & Contact

Thank you for your attention!

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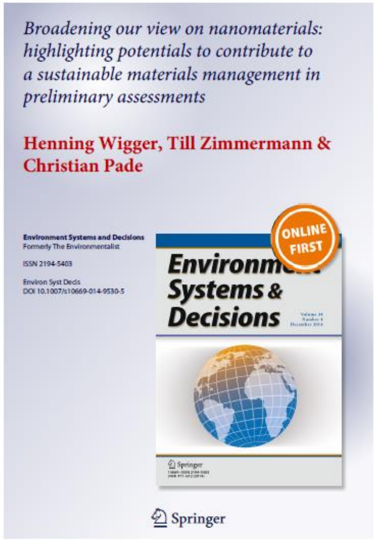
Further reading:



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- Hansen SF, Jensen KA, Baun A (2014) NanoRiskCat: a conceptual tool for categorization and communication of exposure potentials and hazards of nanomaterials in consumer products. J Nanopart Res 16(1). doi:10.1007/s11051-013-2195-z
- Reuter M., Hudson C., Hagelüken C., Heiskanen K., Meskers C., van Schaik A.; (2013) Metal recycling: opportunities, limits, infrastructure UNEP, Nairobi
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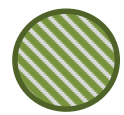
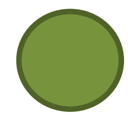
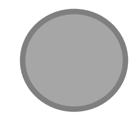
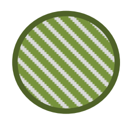
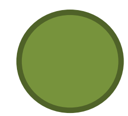
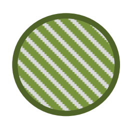
Other preliminary results

Case study	Resource efficiency	Criticality	Dissipation & Release
Permanent magnets (Substitution of rare earth elements)			
Magnetic resonance imaging (Substitution of gadolinium)			
Concrete (reduced cement use through carbon nanotubes)			

Wigger et al. (2014)